Comparative Test of Integrating Wattmeters

Hans Schaedlich
E. W. Cutler

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Comparative Test of
Integrating Wattmeters

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A Comparative Test of Integrating Wattmeters.

A THESIS

PRESENTED BY

Hans Schaedlich.

E. W. Cutler.

TO THE

PRESIDENT AND FACULTY

OF

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FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

1906

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A COMPARATIVE TEST OF INTEGRATING WATTMETERS.

The subject of this thesis as originally outlined was to include both alternating and direct current Wattmeters but owing to the amount of time required for getting the necessary apparatus built and also for actual work on the thesis, the test of alternating current wattmeters had to be left as a possible subject for some future thesis.

In making tests on the wattmeters, our object has been to determine the variation of their accuracy, if any, due to changes of temperature, through ranges, from the highest boiler room temperatures to outdoor temperatures in winter, and also to determine the the cause of these variations, and to note any permament effects resulting from the changes in temperature.

The tests were made upon four well known makes of meters in order to make this work of practical value, by showing the defects and good qualities of commercial instruments when subjected to a large range of temperature

In the beginning work we were confronted, first of all by the question of getting the meters at the temperatures desired for test, and keeping them there for a length of time sufficient for complete tests to be made on each instrument.

For the higher range of temperatures we used for

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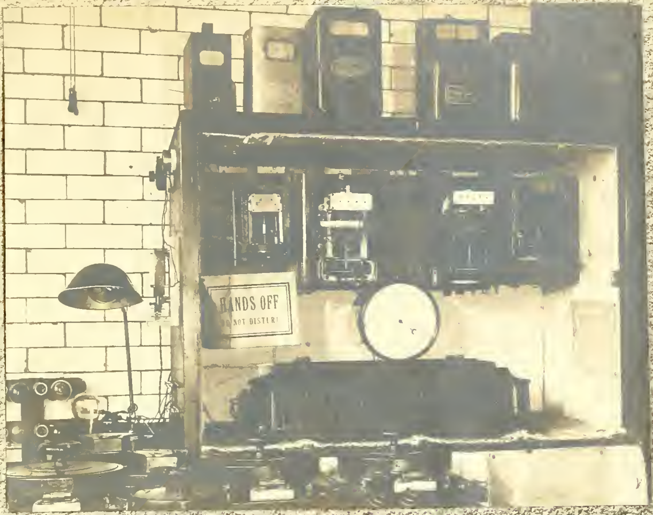
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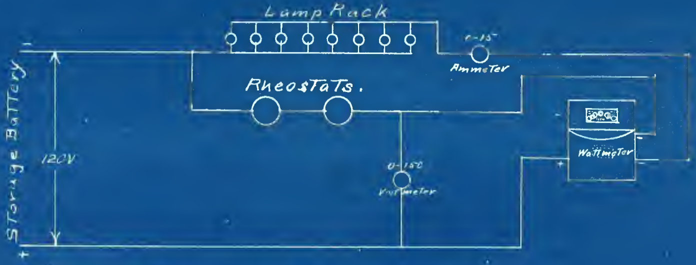


Scheme of Connections

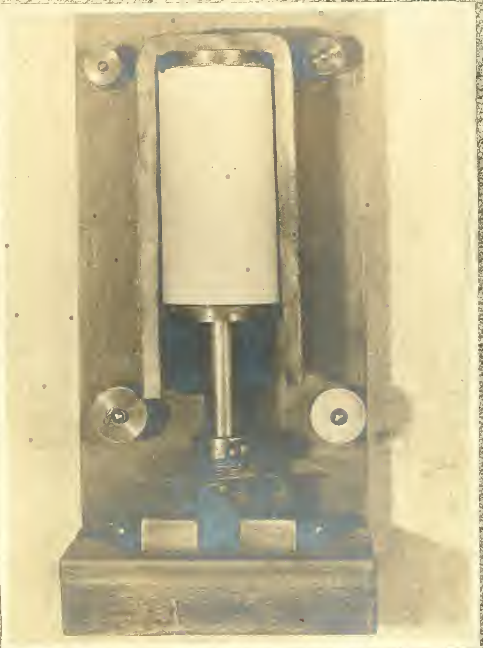
this purpose a large asbestos lined box with a hinged door as shown in the photograph. The meters were placed as in normal operation upon vertical board which was in such position that the meters were equally distant from the front and back of the box.

The series coils of the wattmeters were connected in series with each other and a lamp rack and a calibrated ammeter to a storage battery. The regulation of the current was made by means of the lamp rack, and the close adjustment by means of a rheostat in series with a lamp and in parallel with the lamp rack.

The pressure coils of the meters were connected in multiple across the storage battery. Regulation of potential was obtained by means of several rheostats in series.

Four electric car heaters, of the wire buried in enamel type, were placed in the bottom of the box, and wires run from each of them to terminals on the outside ofthe box.

As originally planned, it was decided to employ some method for automatically keeping the temperature in the box constant at any desired point. The idea evolved for this purpose, was to use some form of relay to open and close the heater circuit, and the relay itself to be operated from the 110 volt mains, when the circuit was



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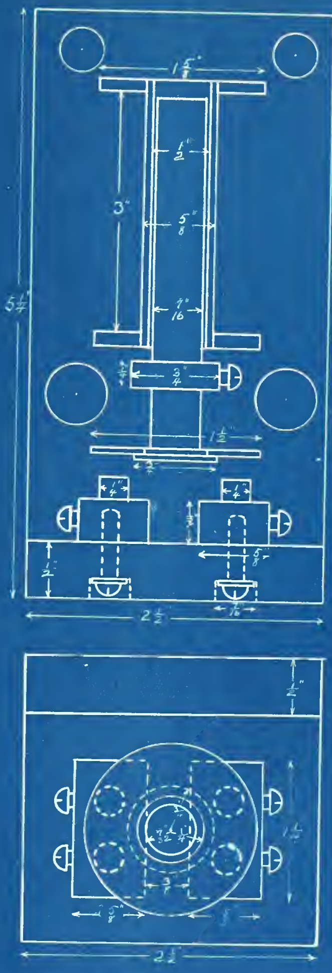


Relay Details

E.W. Cutler

closed by means of a pointer and dial form of thermometer was madeFollowing this idea, an ordinary telegraph relay was made use of, by attaching to the lever arm, a heavy U shaped piece of copper wire the ends of which moved in and out of two mercury cups. In testing this relay with the maximum current it was supposed to carry, we found that the wire did not move far enough out of the cups, to break the arc formed on opening the circuit. Inorder to remedy this defect, we placed transformer oil in the cups upon the mercury, hoping it would break the arc, but though partially successful, this relay prooved unsatisfactory.

In planning a relay which would be satisfactory for the purpose, it was decided to use the principle of thesolenoid. As shown in the blue print of relay details, a brass tube one half inch in diameter, one sixteenth inch thick, and three inches long, forms the shellupon which double cotton covered wire # 33 B & S gauge is wound. Brass end pieces one quarter inch thick, complete the bobbin, and also serve to fasten the coil upon the base board The terminals of the coil are two brass binding posts, placed on the upper part of the base board. The movable core consists of a piece of soft steel turned to a diameter which allows it to move easily in the brass tube. This has a turned steel collar fitted on the lower end of the core held in place by a screw, the cpllar serving the purpose

of keeping a coil spring pressed against a brass disc. This disc is loose upon the core and presses against a small brass washer screwed to the lower end of the rod forming the core. Two heavy brass blocks, each holding two, quarter inch carbons, are solidly fastened to the horizontal part of the "L" shaped base board. When the core is not energized, the brass plate rest upon the tops of the carbons, thus allowing the current toflow through the heaters.

When the circuit ofhthe coil is closed, the core is drawn up, and the brass plate is withdrawn from the carbons, thus opening the heater circuit.

Upon first trying this instrument we found that after heating up, the coil was unable tolift up the core, to remedy this trouble, we placed a "u" shaped piece of wrought iron over the coil. This "u" shaped piece, which proved very effective is not shown in the blue print, but can be plainly seen in the accompanying photograph.

For closing the relay circuit, and thus opening the heater circuit when the temperature reached a predetermined value, we made use of a dial and pointer type of thermometer. Connection was made on the case of the instrument, the current going from there to the pointer, and from the pointer to a movable platinum contact.

The failure of this part of the apparatus was due to

the large heat holding capacity of the heaters. The heaters gave off heat very slowly at the start, causing the thermometer pointer to move slowly up to the contact which was set at the desired temperature. Upon the contact being made, the heater circuit was opened, but the temperature still continued to rise thirty or more degrees above this point. If the heaters had been made of fine wires strung on an open framework, it is highly probable that very accurate regulation could have been obtained by this method.

It was finally decided to regulate the temperature by hand, and as the box holding the meters, was asbestos lined, and allowed the temperature to fall but very little in an hour, we found this method very satisfactory.

In beginning our tests, we kept the pressure constant at 110 volts, the temperature constant at 25 degrees Centigrade, and determined by means of a stop watch and counter, the number of revolutions of the meter in six minutes, for ranges of current from zero to one hundred per cent load. The curves thus obtained, vary for the different wattmeters, and will be discussed later.

In order to have a complete analysis of the characteristics of the wattmeters, we kept the temperature constant at 25 degrees centigrade, and for certain values of current varied the voltage from eightyfive to one hundred and twenty volts. From the data thus obtained we plotted curves, with voltage on one axis and per cent accuracy on the other. As one of the

meters tested, the Halsey, is of a type without pressure regulation this meter was excluded from the above test.

The first of the above tests was repeated at constant temperatures ranging from twenty-five to eighty degrees centigrade. Lower temperatures were not obtained, because of the failure at a late date of our apparatus for that purpose. After making tests at the higher temperatures, we repeated it at thirty degrees centigrade in order to determine wether permament change in accuracy was caused by too high temperatures, the results of this test will be discussed later.

The wattmeters tested are of two types, the first, ofwhich the Thomson and Duncan are representative, consist of four primary elements, a rotating armature, a stationary field, a metallic damping disc fastened to the armature shaft, and passing between the jaws of permament magnets, and a registering device, the function of which is to integrade the instantaneous values of the electrical energy passing through the meter.

The element causing rotation is the motor which being without iron in its field and armature, and rotating at a low speed, has little counter electromotive force generated. For this reason its armature current is independent of the speed of rotation, and is dependent upon the potential applied at its terminals. The torque of the motor is proportional tot e energy passing through its coils. Now in order to make the speed propor-

tional to this torque, a load or drag is applied the strength of which is directly proportional to the speed.

It is a well established fact that the electromotive force induced in a conductor passing through a field which remains constant, is proportional to the number of lines of flux cut per unit time. Assuming that resistance of the conductor does not vary, the induced electromotive force and therefore the drag on the conductor is proportional to the speed. This is the principle used in producing the drag on the armature of the meter. The field is obtained by permanent horseshoe magnets

The dial or integrating mechanism, consists of a revolution counter calibrated in kilowatt-hours. Specificdetails of the different instruments will not be discussed here, as these may be found in the catalogues of the various companies making the meters.

The second type of meter is represented by the Halsey meter, the principle of which is that of an ampere hour meter in which the main curront passes through a metallic disc floated in mercury, and rotating in the field of a powerful permament magnet. The disc is caused to rotate by the current which traverses it radially through the dense magnetic field,passing in and out trough two copper lead wires which are immersed in the mercury. Thelargest part of the current passes through the

disc as its conductivity is about 5.8 times that of mercury. It is evident that the current will develope in the disc a torque, and also velocity, in direct proportion to itself, as the speed of rotation is retarded in direct proportion to the current by Foucalt or eddy currents generated in the disc, by the strong field.

Discussion of Results and Conclusions.

In order to be certain that the results obtained were correct, we carefully calibrated the ammeter and voltmeter, and plotted correction curves for them. From these from these curves we found the values corresponding to the values we wished to use. Bythis means we eliminated the errors which would undoubtably have crept in if we had attempted to correct the data after accumulating it.

The curve of the Duncan meter, showing the effect of variation of current with constant voltage and temperature, starts at about 109 % at low values of current and drops to about100 % at 5amperes in a slight curve. From here to 15 amperes thecurve appears tobe naearly a straight line, this point showing about 94 % registered. It should be noted in this and in the other curves that the wattmeters were not adjusted to give correct readings at any particular point, as only the effects on the registration of varying conditions were sought.

The Thomson type "W" curve, has a form, directly opposite to that of the Duncan meter in that it registers low at low values of the current, and high at the high values.

The Thomson type "C" is from three to fifteen amperes nearly a straight line, sloping from 100 % to 98 %.

The Halsey curve is a straight line sloping from 100 % to 98 % at fifteen amperes.

The pressure curves of all of the wattmeters have a general slope downward as the voltage is increased and this is probably due to increased leakage.

The curves of the Duncan meter, showing the effects of temperature, are all concave downward, its curvature becoming more mark for the lower values of current. Heat causes the resistance of the pressure coil of the wattmeter to increase, this decreasing the flux and causing the meter to run slower. The heating of the disc causes its resistance to rise also , thus diminishing the retarding force, and having the effect of speeding up the meter, The shape of the curve will depend upon the relative magnitudes of these two effets predominates.

In the Thomson type" " meter the curve slopes upward becoming steeper as the temperature increases, and the effect more marked as the current is diminished.

The curves of the Thomson type "C" meter show the same general characteristics as those of the type "W" meter, but the effects are very much less pronounced and at ordinary temperatures run on a practically horizontal part of the curve.

The Halsey meter again shows the same general form of curve as the Duncan meter, but the curve is very

much flatter than that of the Duncan meter.

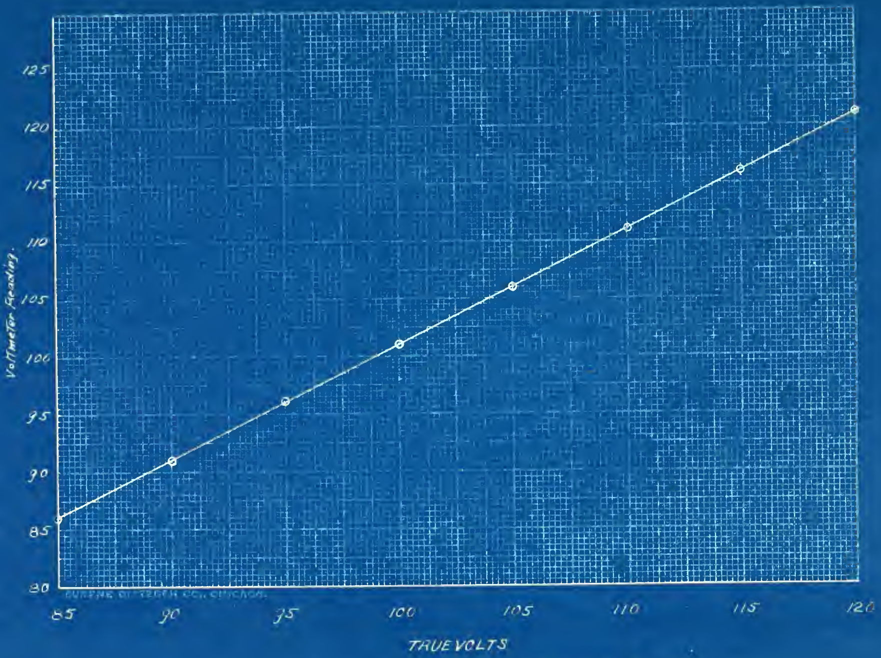
The damping discs of the Duncan and type "C" Thomson wattmeters are made of aluminum, while those of the Halsey and type "M" Thomson meters are made of copper. This shows that the difference in the shapes of the curves is not due to the materials of the discs alone. Since the construction of the type"M" and that of the Duncan meters are very similar, we may say that while the materials used in the damping discs and the design of the current carrying parts undoubtably effect the magnitude of the variation,it is my opinion that the shape of the curve is chiefly effected by the iron of the damping magnets. However as we had no means of verifying this we must give it as an opnion only.

Data and

Performance Curves.

Calibration of Weston Voltmeter # 4320 (0_150)

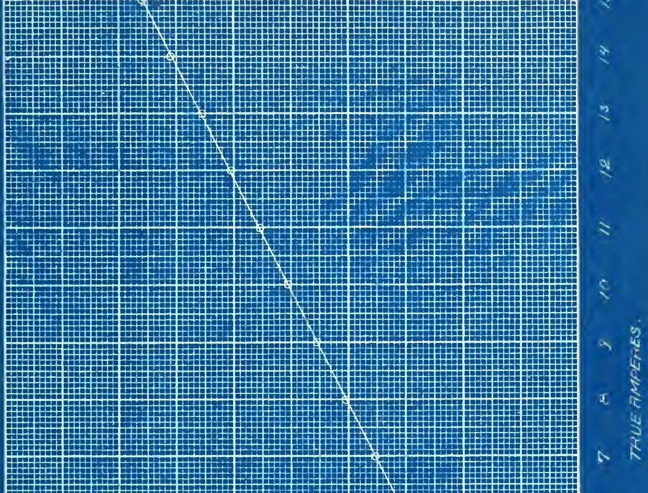
TRUE VOLTS	VOLTMETER READING
85	86
90	91
95	96
100	101
105	106
110	111
115	116
120	121



Calibration of Weston Voltmeter #4320 (0-150)

Calibration of Weston Ammeter # 4088 (0 15)

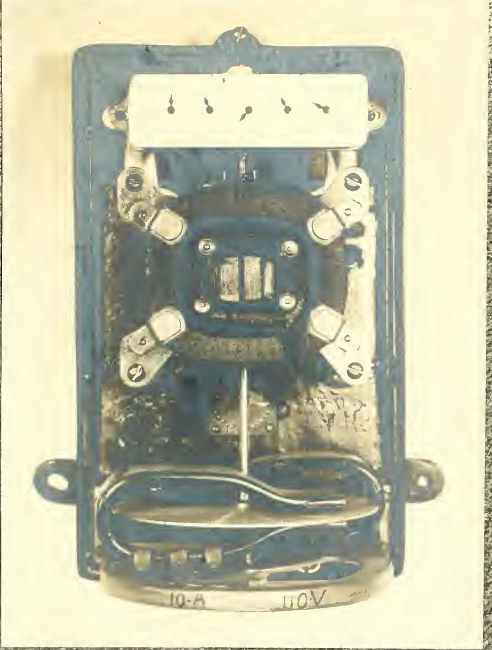
TRUE AMPERES	AMMETER READING
1	1
2	2.01
3	3.02
4	4.03
5	5.04
6	6.05
7	7.06
8	8.08
9	9.09
10	10.09
11	11.08
12	12.09
13	13.1
14	14.2
15	15.2



Calibration of Weston Ammeter #4088 (0-15)

Duncan

Integrating Wattmeter.


10-A
110-V

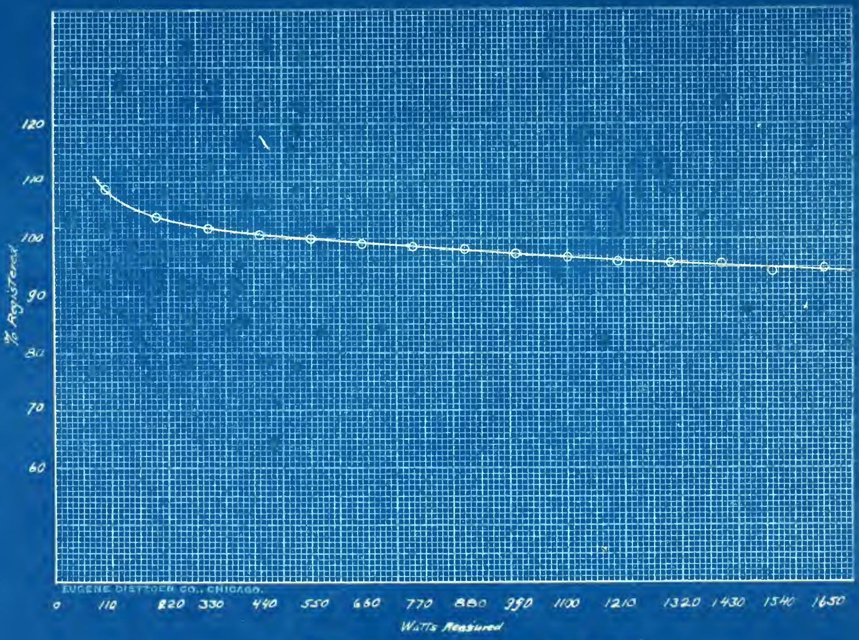
Duncan Integrating Wattmeter.

Data showing the effect of change of current at normal voltage.

Potential = 110 volts.

CURRENT Temperature = 25 degrees C.

CURRENT	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
1	110	120.3	109.3
2	220	222.2	101.
3	330	336.8	102.
4	440	444.3	100.7
5	550	548.5	99.7
6	660	652.5	98.9
7	770	757.5	98.4
8	880	868.	98.6
9	990	967.	97.5
10	1100	1065.	96.9
11	1210	1160.5	96.
12	1320	1269.	96
13	1430	1369.	95.8
14	1540	1442.	93.6
15	1650	1561.	94.7



Performance Curve of Duncan Integrating Wattmeter
Showing The Effect of Variation of Current
With Constant Voltage and Temperature

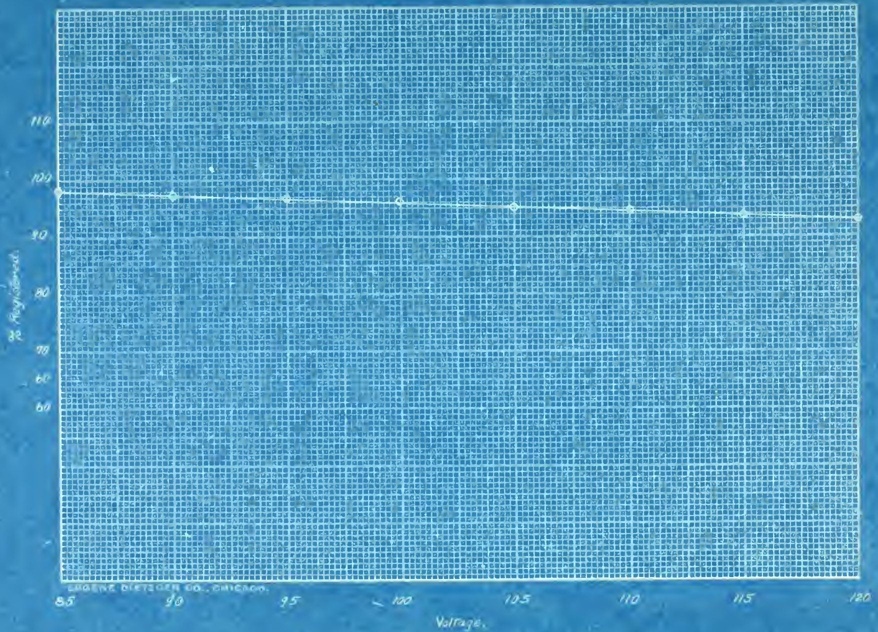
Duncan Intgrating Wattmeter.

Data showing the effect of change of voltage at 150 % load

Current = 15 amperes.

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	1275	1251	98.1
90	1350	1310	97.
95	1425	1383	97.1
100	1500	1442	96.1
105	1575	1495	94.9
110	1650	15[illegible]	94.7
115	1725	1621	93.9
120	1800	1669	92.6



Performance Curve of Duncan Integrating Wattmeter
Showing the Effect of Variation of Voltage at 150% Load
With Current and Temperature Constant.

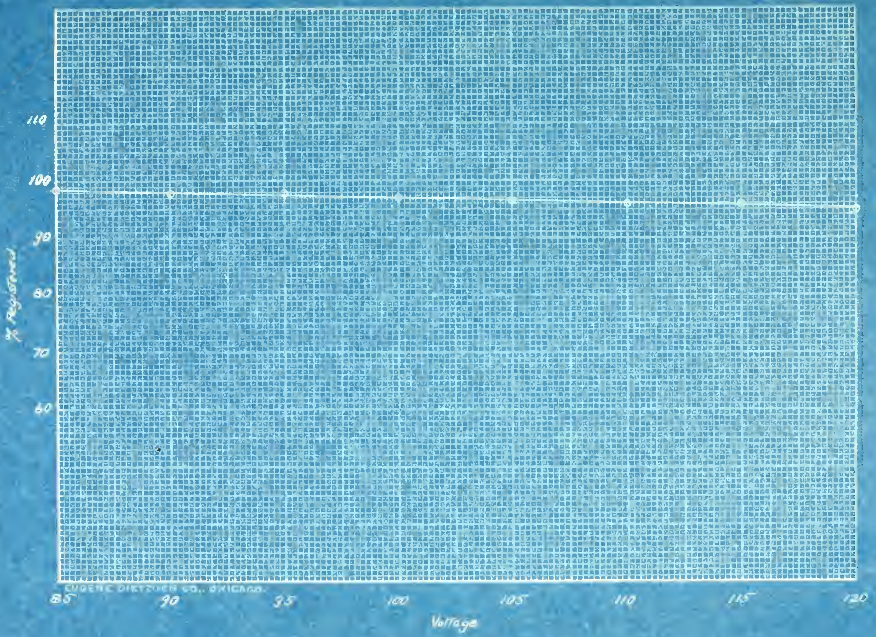
Duncan Integrating Wattmeter.

Data showing the effect of change of voltage at 125 % load.

Current = 12.5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	1062.5	1045	98.4
90	1125.	1099.	97.9
95	1187.5	1163	98.1
100	1250.	1209	96.9
105	1312.5	1267	96.5
110	1375.	1319	95.9
115	1437.5	1377	95.8
120	1500	1420	94.6



Performance Curve of Duncan Integrating Wattmeter
Showing the Effect of Variation of Voltage at 125% Load
With Current and Temperature Constant

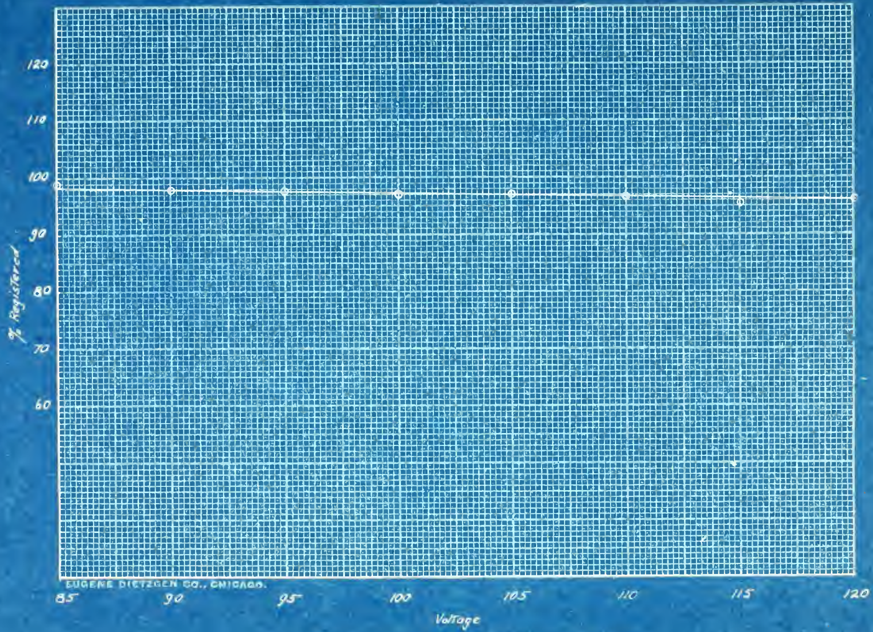
Duncan Integrating Wattmeter.

Data showing the effect of change of voltage at 100 % load.

Current = 10 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	850	840.	98.9
90	900	881	97.9
95	950	925.5	97.4
100	1000	969.5	96.95
105	1050	1019.	97.
110	1100	1065.	96.9
115	1150	1097.	95.5
120	1200	1152	95.9



Performance Curve of Duncan Integrating Wattmeter
Showing the Effect of Variation of Voltage at 100% Load
With Current and Temperature Constant

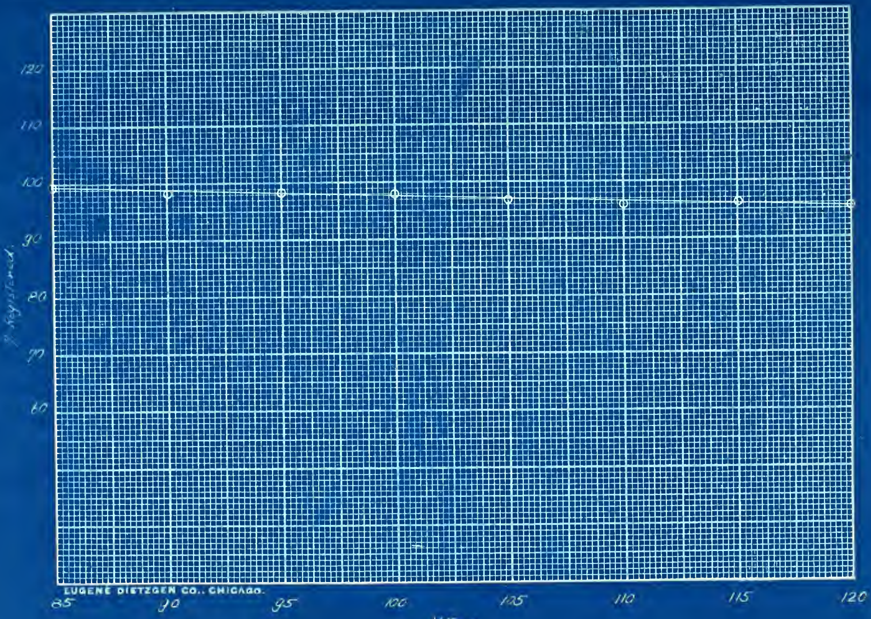
Duncan Integrating Wattmeter.

Data showing the effect of change of voltage at 75 % load.

Current = 7.5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	637.5	635.	99.5
90	675.	662.	98.1
95	712.5	699.	98.
100	750.	735.5	98.1
105	787.5	762.5	97.
110	825.	795.8	96.5
115	862.5	833.	96.6
120	900.	859.	95.4



Performance Curve of Duncan integrating Wattmeter
Showing the Effect of Variation of Voltage at 75% Load
With Current and Temperature Constant.

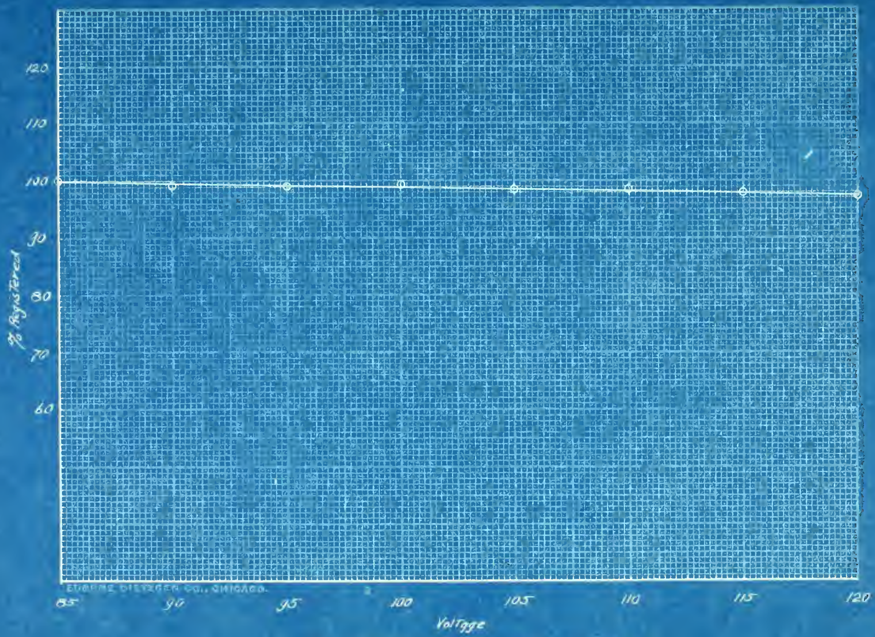
Duncan Integrating Wattmeter.

Data showing the effect of change of voltage at 50 %load.

Current = 5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	425	425.5	100.1
90	450	446.	99.1
95	475	470.5	99.1
100	500	497.	99.4
105	525	516.5	98.5
110	550	541.	98.4
115	575	563.5	97.9
120	600	584.	97.3



Performance Curve of Duncan Integrating WattMeter
Showing the Effect of Variatio of Voltage at 50% Load
With Current and Temperature Constant.

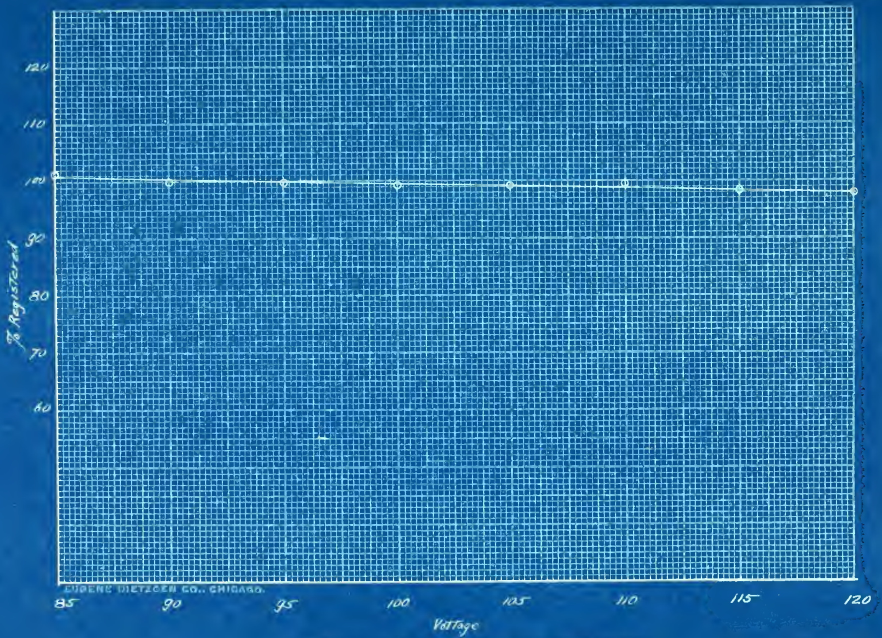
Duncan Integrating Wattmeter.

Data showing the effect of change of voltage at 25 % load.

Current = 2.5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	212.5	214.7	101.
90	225.	224.8	99.9
95	237.5	236.8	99.8
100	250.	247.7	99.1
105	262.5	260.	99.
110	275.	272.4	99.1
115	287.5	283.	98.6
120	300.	293.	97.7



Performance Curve of Duncan Integrating Wattmeter
Showing The Effect of Variation of Voltage at 25 % Load
With Current and Temperature Constant

Duncan Integrating Wattmeter.

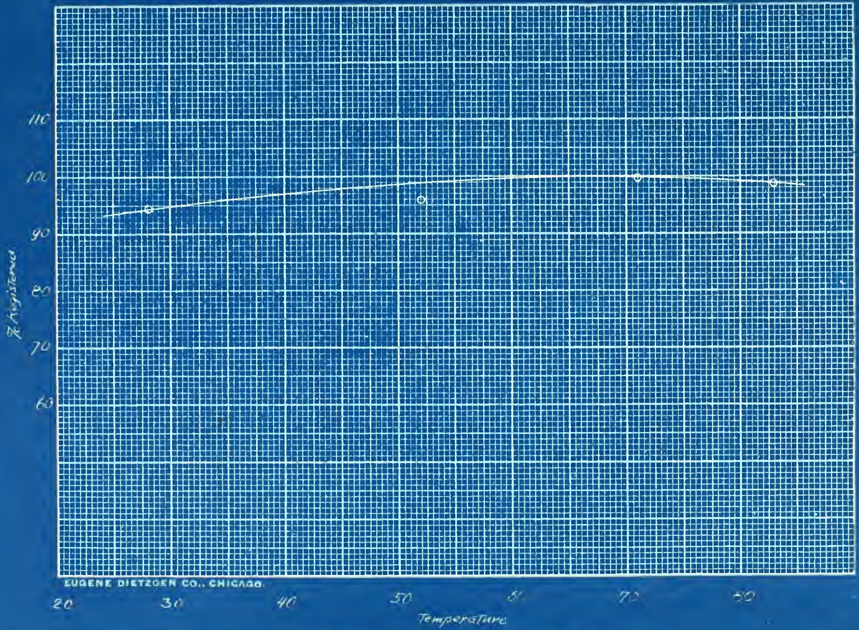
Data showing the effect of change of temperature at 150 % load

Potential = 110 volts

Current = 15 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
28	1650	1560	94.5
52	1650	1590	96.
71	1650	1655	100.3
83	1650	1630	98.8

3.2



Performance Curve of Duncan Integrating Wattmeter
Showing the Effect of Variation of Temperature
At 75% Load With Pressure and Current Constant.

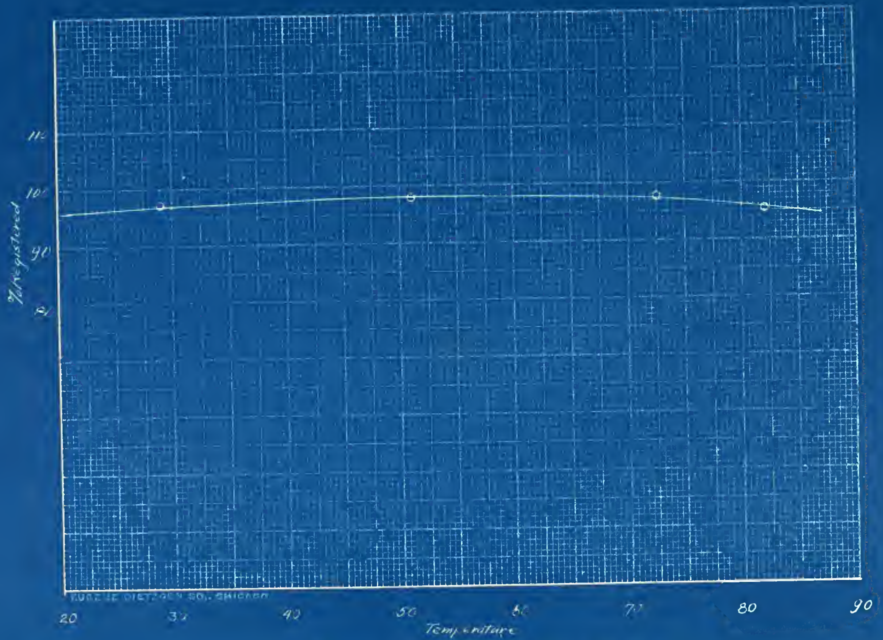
Duncan Integrating Wattmeter.

Data showing the effect of change of temperature at 125 % load

Potential =110 volts

Current = 12.5 amperes

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
28.	1375	1335	97.3
51	1375	1345	98.
72.5	1375	1345	98.
82.	1375	1310	95.5



Performance Curve of Duncan Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 125% Load with Constant Voltage and Current

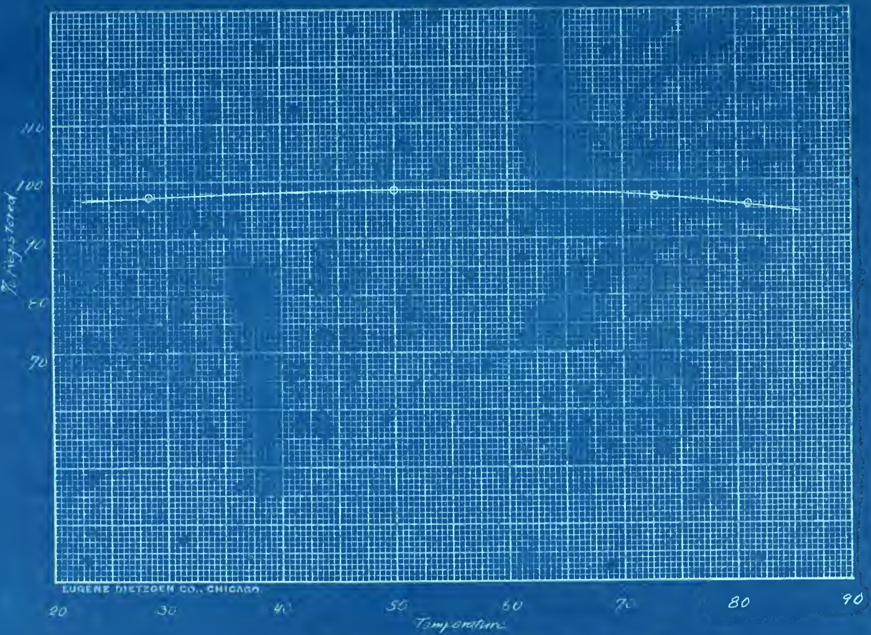
Duncan Integrating Wattmeter.

Data showing the effect of change of temperature at 100 % load.

Potential = 110 volts

Current = 10 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
28.5	1100	1069	97.2
50.	1100	1081	98.5
72.8	1100	1065	97.
91.	1100	1052	95.6



Performance Curve of Duncan Integrating Wattmeter
Showing The Effect of Variation of Temperature
at 100 % Load with Constant Voltage and Current

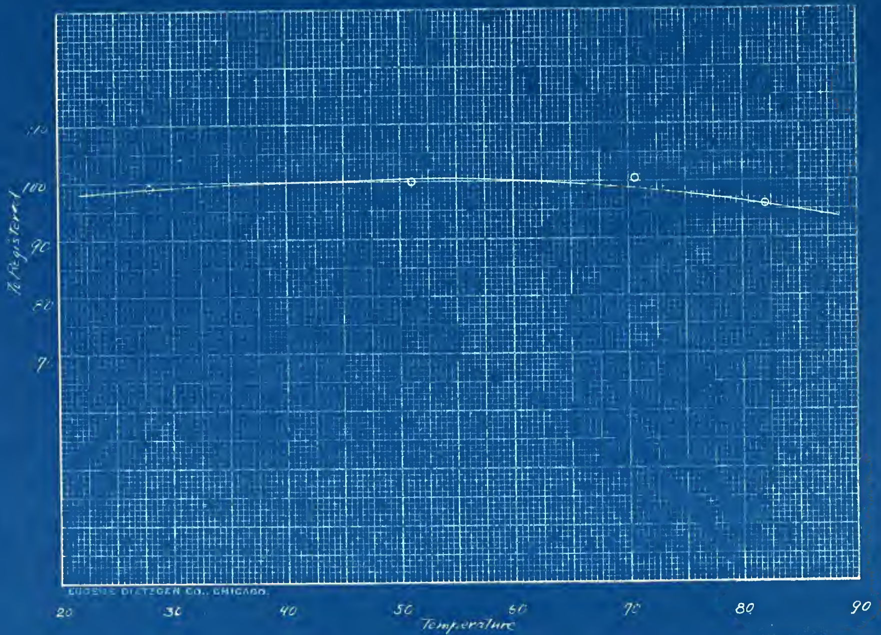
Duncan Integrating Wattmeter.

Data showing the effect of change of temperature at75 % load

Potential =110 volts

Current = 7.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
29.	825	820	99.3
51.	825	826	100.
70.9	825	830	100.5
99	825	792	96.



Performance Curve of Duncan Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 75% Load with Constant Voltage and Current.

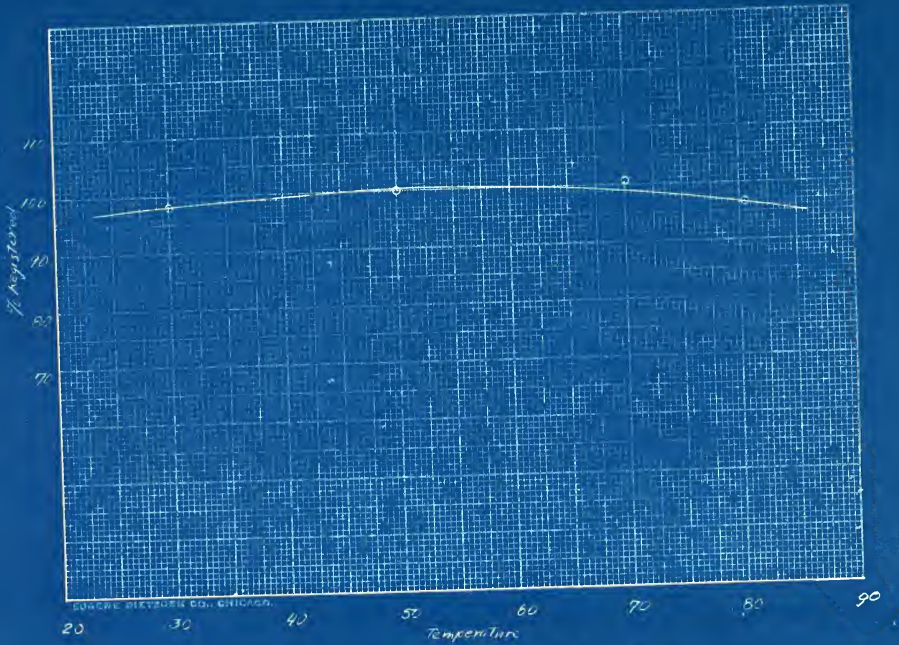
Duncan Integrating Wattmeter.

Data showing the effect of change of temperature at 50 % load.

Potential = 110 volts

Current = 5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30	550	540	98.2
50	550	550	100.
70	550	554	100.7
81	550	532	96.8



Performance Curve of Duncan Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 50 % Load with Constant Voltage and Current

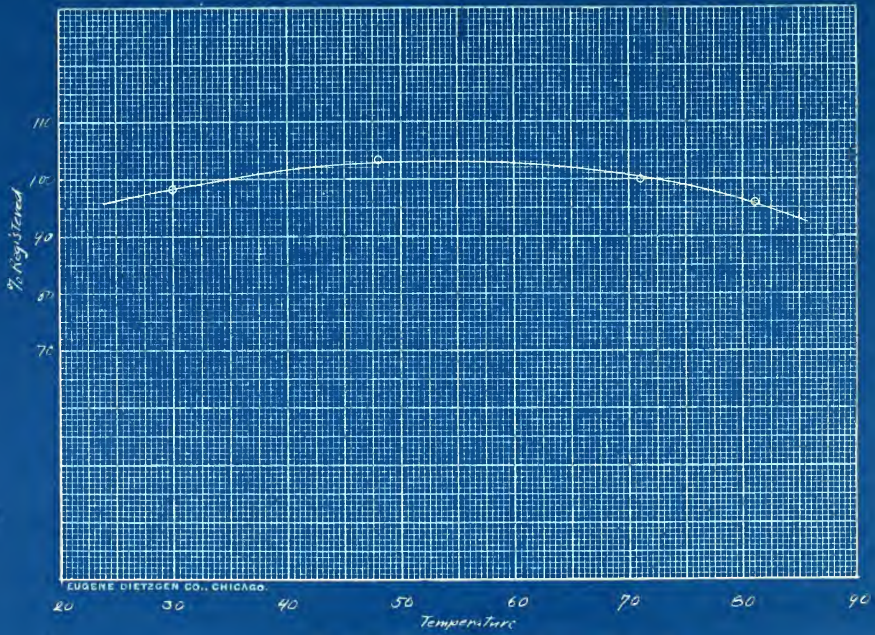
Duncan Integrating Wattmeter.

Data showing the effect of change of temperature at 25 % load.

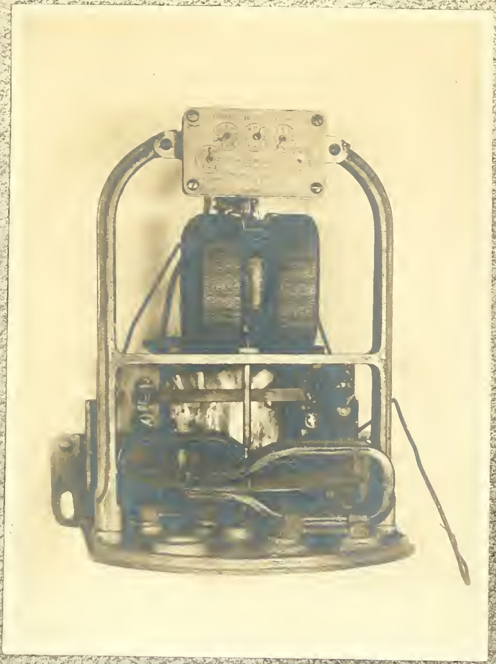
Potential = 110 volts

Current = 2.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30	275	270.1	98.4
48	275	284.	103.3
71	275	275.8	100.1
91	275	263	95.8



Performance Curve of Duncan Integrating Wattmeter
Showing The Effect of Variation of Temperature
at 25% Load with Constant Voltage and Current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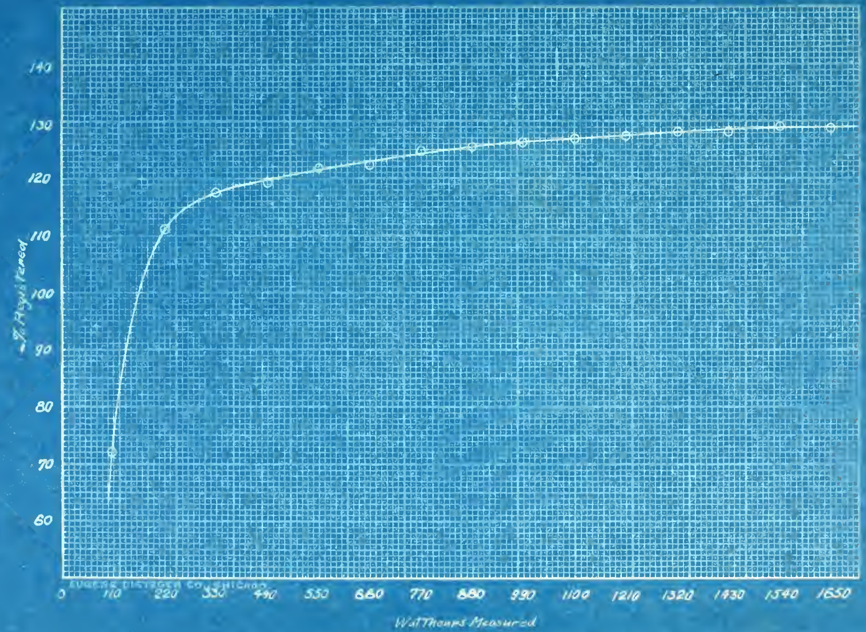
Thomson-Houston Type "M" Integrating Wattmeter.

Data showing the effect of change of current at normal voltage.

Potential = 110 volts

Temperature = 25 degrees.

CURRENT	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
1	110	79.	71.8
2	220	240.6	110.9
3	330	388.1	117.5
4	440	524.	119.
5	550	672.5	122.
6	660	804.5	121.7
7	770	966.7	125.5
8	880	1103.	125.5
9	990	1251.	126.3
10	1100	1397.	127.
11	1210	1545.1	127.7
12	1320	1697.	128.5
13	1430	1826.	128.
14	1540	1986.	129.
15	1650	2136.	129.4



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Current
With Constant Voltage and Temperature

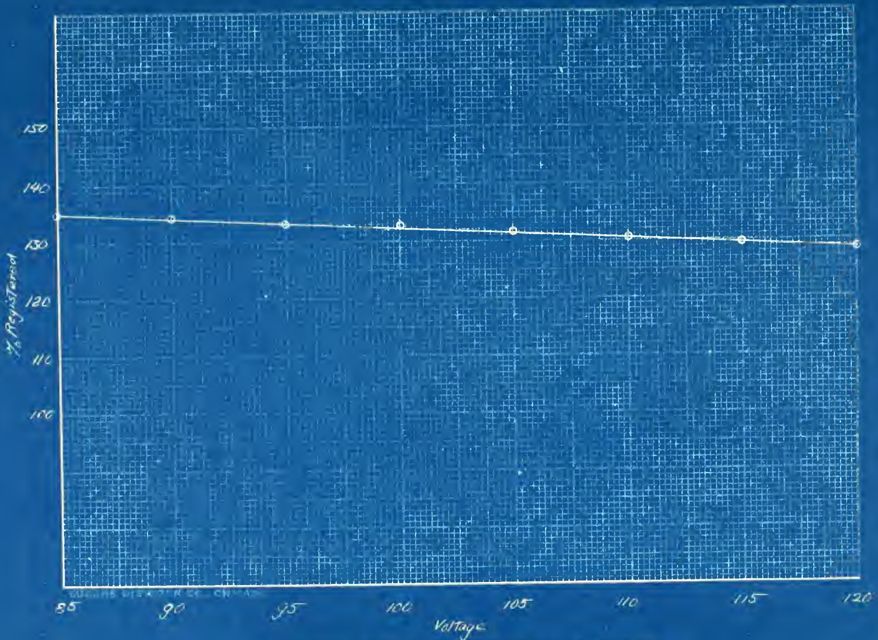
Thomson-Houston Type "M" Integrating Wattmeter.

Data showing the effect of change of voltage at 150 % load.

Current = 15 amperes

Temperature =25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	1275	1722	135.1
90	1350	1814	134.4
95	1425	1895	133.
100	1500	1996	133.1
105	1575	2064	131.5
110	1650	2155	130.6
115	1725	2234	129.6
120	1800	2311	128.4



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Voltage at 150 % Load
With Current and Temperature Constant

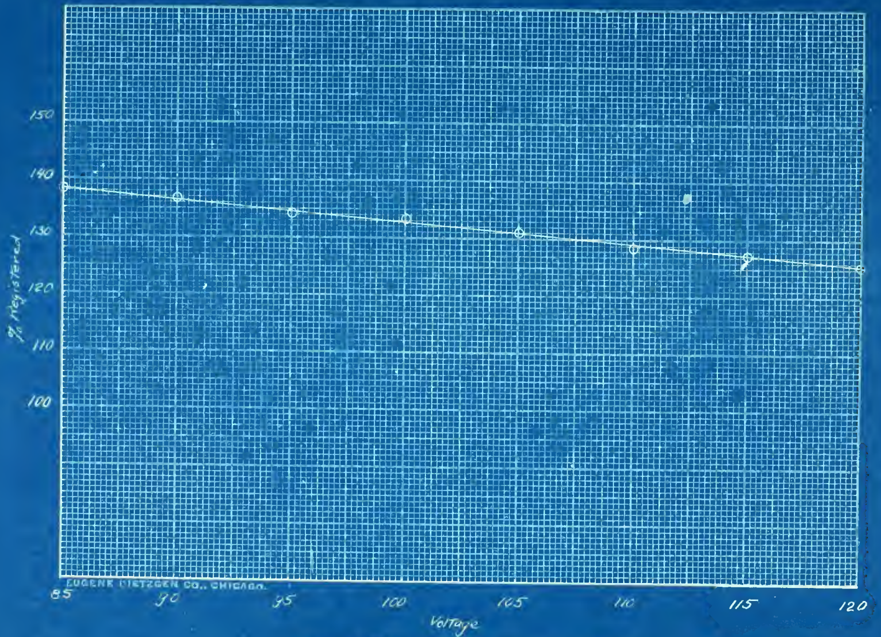
Thomson-Houston Type "[illegible]" Integrating Wattmeter.

Data showing the effect of changing of voltage at 125 % load.

Current = 12.5 amperes

Temperature = 15 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	1062.5	1481	139.4
90	1125.	1528	135.8
95	1187.5	1594	134.3
100	1250.	1669	133.5
105	1312.5	1720	131.
110	1375.	1780	129.5
115	1437.5	1837	127.8
120	1500.	1885	125.7



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Voltage at 125% Load
With Current and Temperature Constant

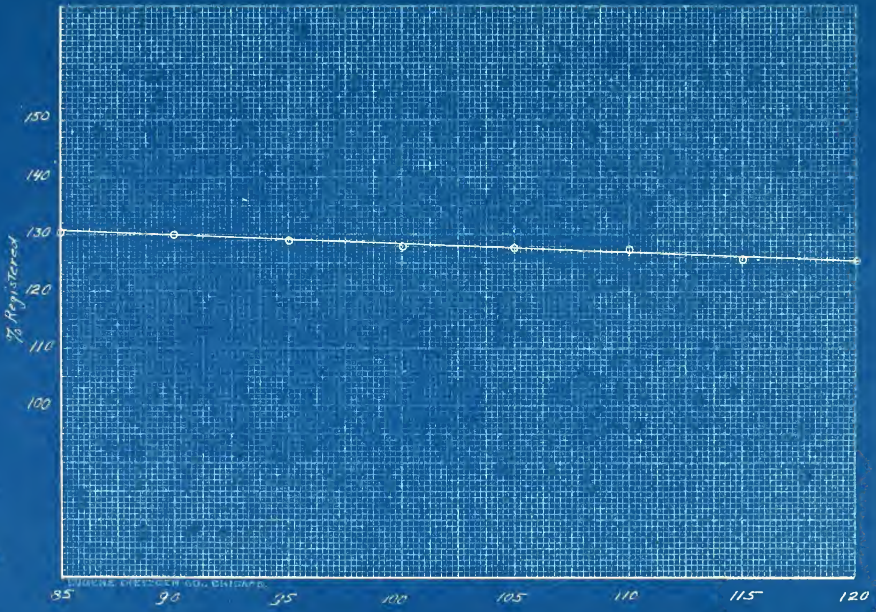
Thomson-Houston Type "M" Integrating Wattmeter.

Data showing the effect of change of voltage at 100 % load.

Current =10 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	850	1108	130.3
90	900	1170	130.
95	950	1223	128.8
100	1000	1280	128.0
105	1050	1341	127.7
110	1100	1402	127.5
115	1150	1447	125.9
120	1200	1499	124.9



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Voltage at 100 % Load
With Current and Temperature Constant

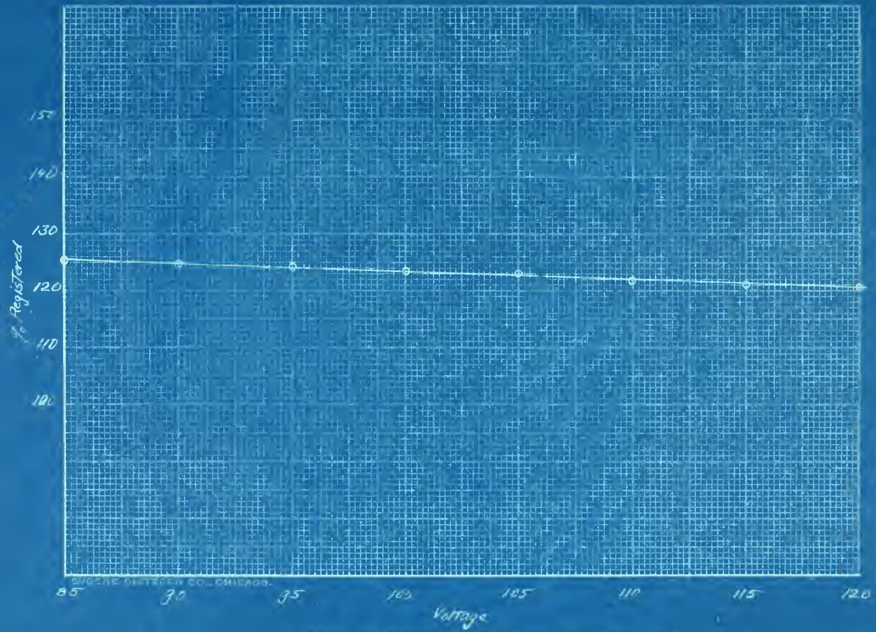
Thomson-Houston Integrating Wattmeter.

Data showing the effect of change of voltage at 75 % load.

Current = 7.5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	637.5	801.	125.5
90	675.	842.	124.9
95	712.5	885.5	124.2
100	750.	925.	123.5
105	787.5	969.	123.
110	825.	1003.	121.7
115	862.5	1045.	121.
120	900.	1085.	120.5



Curve of Thomson Type M Integrating Wattmeter
Showing The Effect of Variation of Voltage at 75% Load
With Current and Temperature Constant.

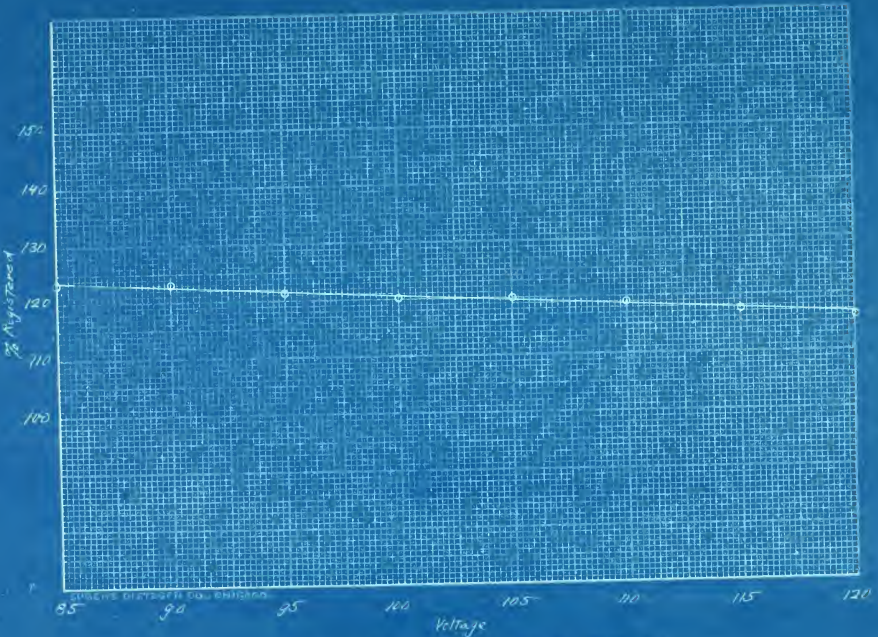
Thomson-Houston Type "M" Integrating Wattmeter.

Data showing the effect of change of voltage at 50 % load.

Current = 5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	425	524.5	123.2
90	450	553.5	123.
95	475	576.	121.4
100	500	602.	120.2
105	525	625.	119.0
110	550	647.5	117.9
115	575	676.	117.7
120	600	697.	116.1



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Voltage at 50% Load
With Current and Temperature Constant

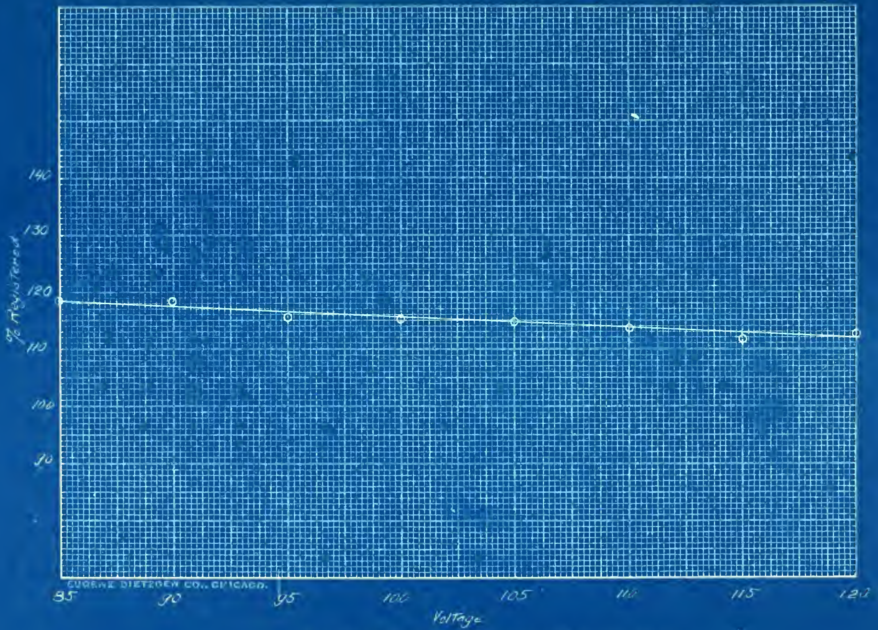
Thomson-Houston Type "[illegible]" Integrating Wattmeter.

Data showing the effect of change of voltage at 25 % load.

Current = 2.5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	212.5	240.	118.4
90	225.	266.7	118.5
95	237.5	27[illegible].1	115.5
100	250.	287.9	115.1
105	262.5	301.5	114.8
110	275.	307.	113.7
115	287.5	320.8	111.9
120	300.	337.5	112.5



Curve of Thomson Type M Integrating Wattmeter
Showing The Effect of Variation of Voltage at 25% Load
With Current and Temperature Constant

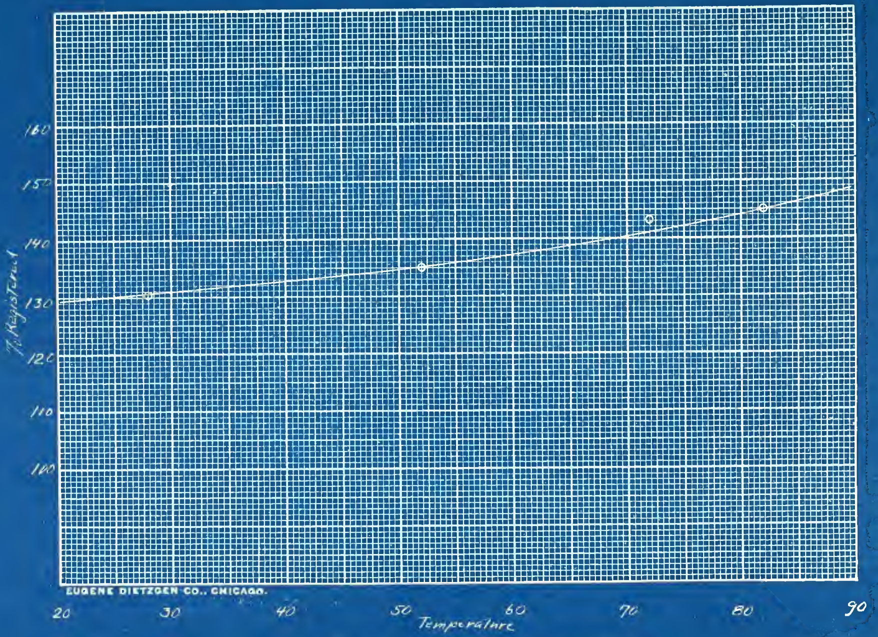
Thomson- Houston Type "M" Integrating Wattmeter.

Data showing the effect of change of temperature at 150 % load.

Potential = 110 volts

Current = 15 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
28	1650	2151	130.5
52	1650	2223	135.
72	1650	2362	143.3
82	1650	2398	145.



Curve of Thomson Type M Integrating Wattmeter
Showing The Effect of Variation of Temperature
at 150 % Load with Constant Voltage and Current

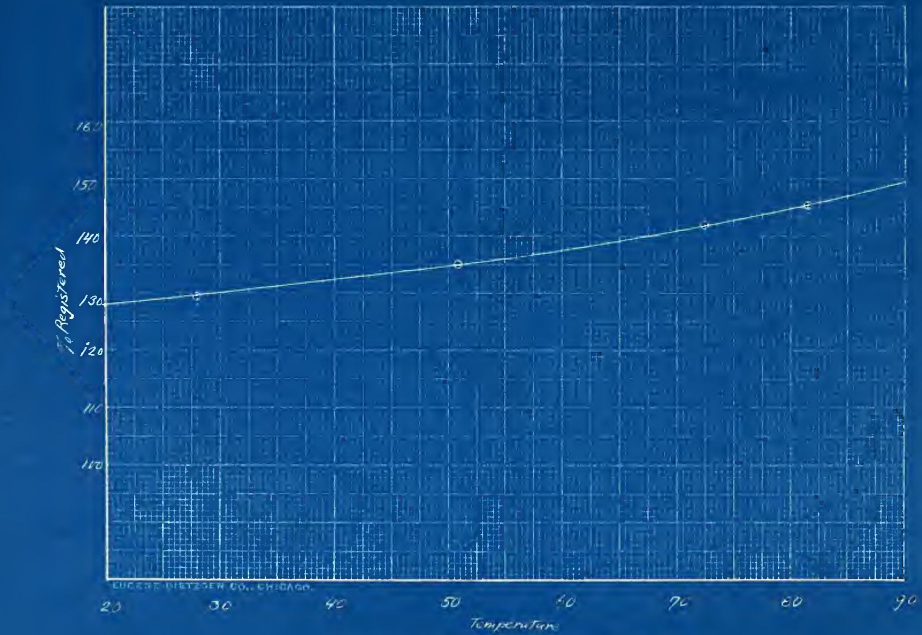
Thomson-Houston Type "[illegible]" Integrating Wattmeter.

Data showing the effect of change of temperature at 125 % load.

Potential = 110 volts

Current = 12.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
28.	1375	1780	129.4
51.	1375	1859	135.
72.5	1375	1950	141.8
91.5	1375	1995	145.2



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 125 % Load with Constant Voltage and Current.

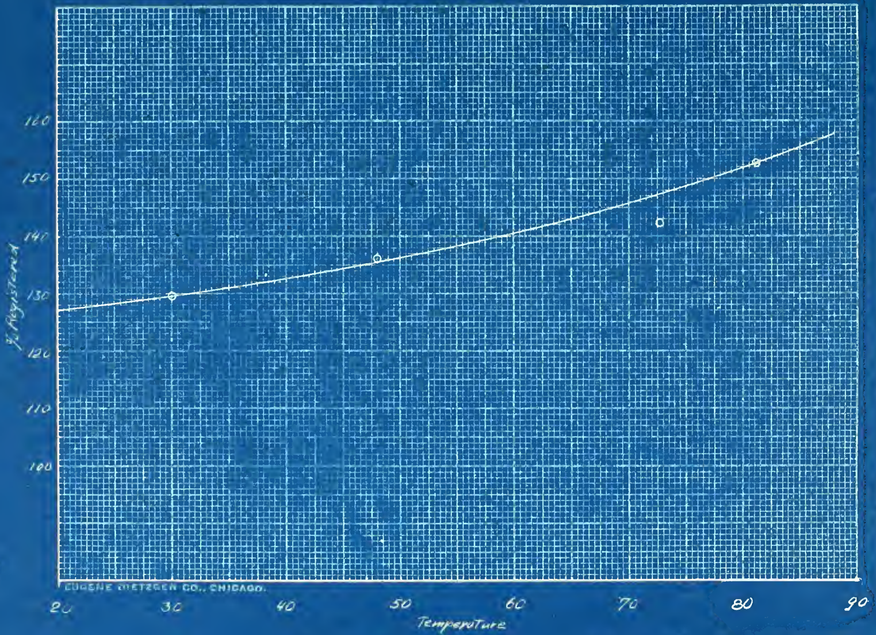
Thomson-Houston Type "[illegible]" Integrating Wattmeter.

Data showing the effect of change of temperature at [illegible] % load.

Potential =110 volts

Current = 10 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30.	1100	1425	129.5
48.	1100	1500	136.5
72.5	1100	1550	141.0
81.			



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 100 % Load with Constant Voltage and Current

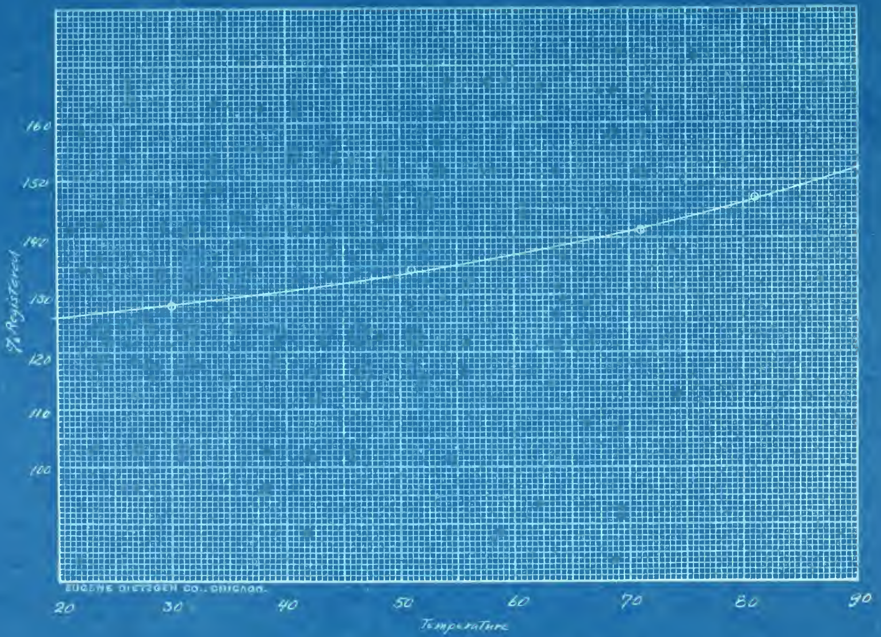
Thomson-Houston Type "[illegible]" Integrating Wattmeter.

Data showing the effect of change of temperature at 75 % load.

Potential = 110 volts

Current = 7.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30	825	1065	129.
51	825	1110	134.5
71	825	1165	141.2
91	825	1211	147.



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 75% Load with Constant Voltage and Current

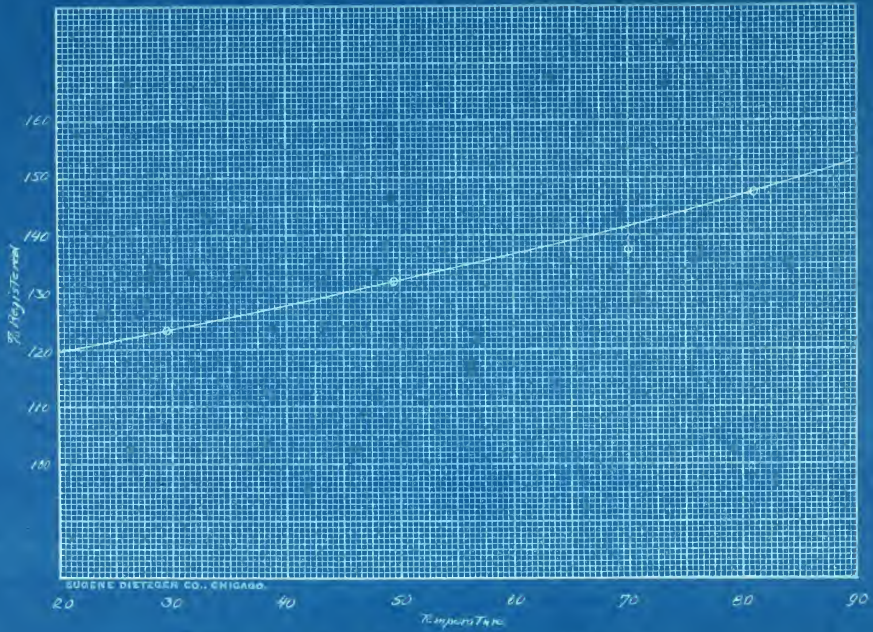
Thomson-Houston Type "A" Integrating Wattmeter.

Data showing the effect of change of temperature at 50 % load

Potential = 110 volts

Current = 5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
29.5	550	679.5	123.3
49.5	550	728.5	132.9
70.	550	757.	137.5
81.	550	813.5	147.5



Curve of Thomson Type M Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 50 % Load with Constant Voltage and Current

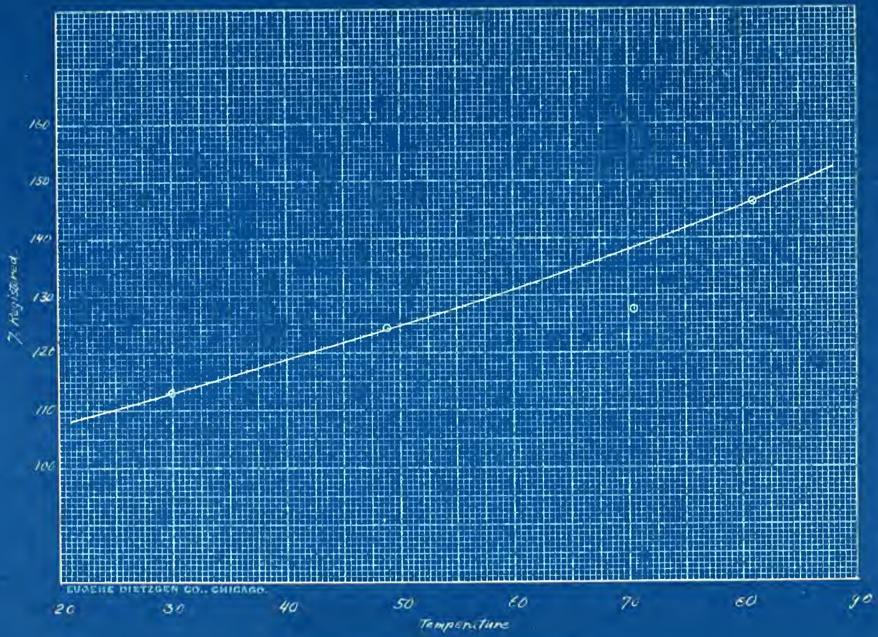
Thomson-Houston Type "K" Integrating Wattmeter.

Data showing the effect of change of temperature at 25 % load.

Potential = 110 volts

Current = 2.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30.	275	311.	113.
40.	275	341.7	124.2
70.5	275	350.	127.3
81.	275	401.	146.



Curve of Thomson Type "M" Integrating Wattmeter
Showing the Effect of Variation of Temperature
At 25% Load With Pressure and Current Constant.

Thomson Houston Type C

Integrating Wattmeter.

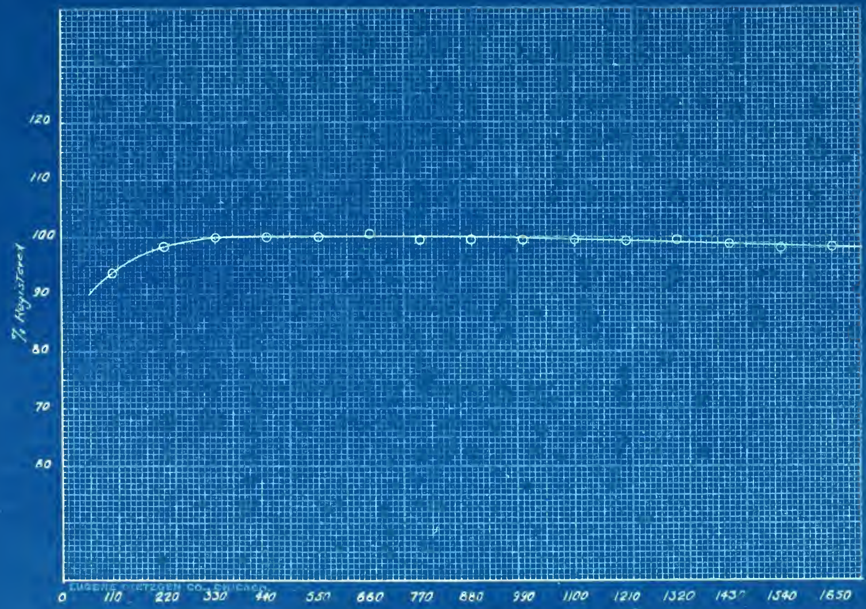
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of current at normal voltage.

Potential = 110 volts

Temperature = 25 degrees C.

CURRENT	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
1	110	103.3	93.9
2	220	217.2	98.7
3	330	333.3	100.1
4	440	440.8	100.2
5	550	549.	99.8
6	660	662.9	100.4
7	770	765.	99.4
8	880	876.	99.5
9	990	984.4	99.4
10	1100	1093.9	99.5
11	1210	1202.	99.6
12	1320	1314.	99.6
13	1430	1415.6	99.
14	1540	1509.6	99.1
15	1650	1627.	98.6



Curve of Thomson Type C Integrating Wattmeter
Showing The Effect of Variation of Current
With Constant Voltage and Temperature.

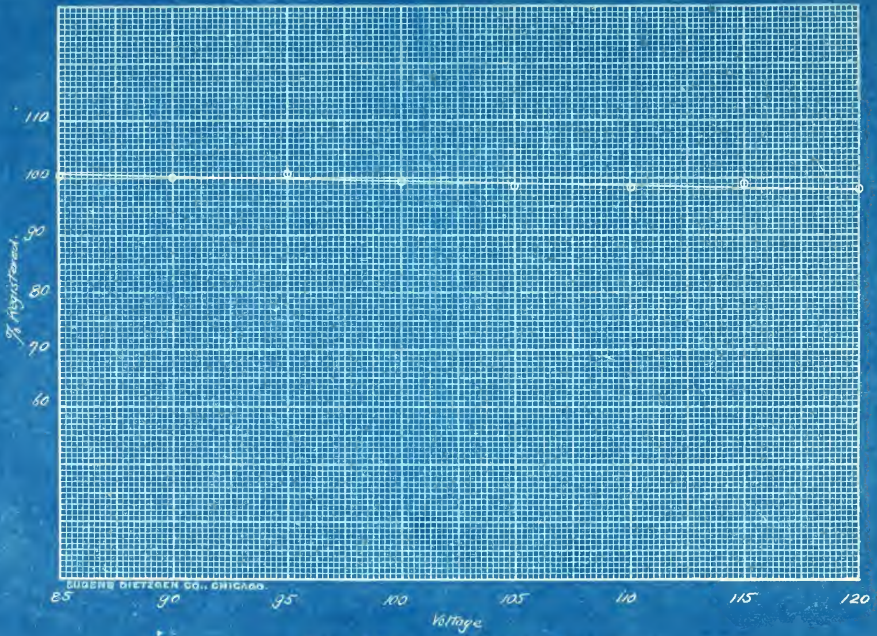
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of voltage at 150 % load.

Current =15 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	1275	1281	100.5
90	1350	1347	99.8
95	1425	1437	100.8
100	1500	1488	99.2
105	1575	1550	98.5
110	1650	1627	98.6
115	1725	1709	99.
120	1800	1763	98.



Curve of Thomson Type C Integrating Wattmeter
Showing the Effect of Variation of Voltage at 150% Load
With Current and Temperature Constant.

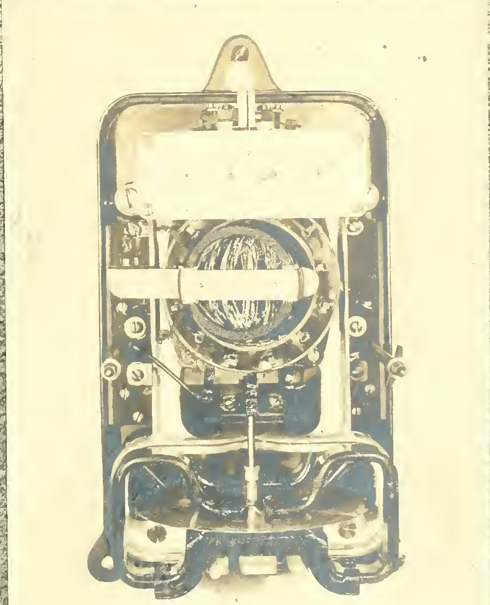
Thomson-Houston Type "C" Integrating Wattmeter.

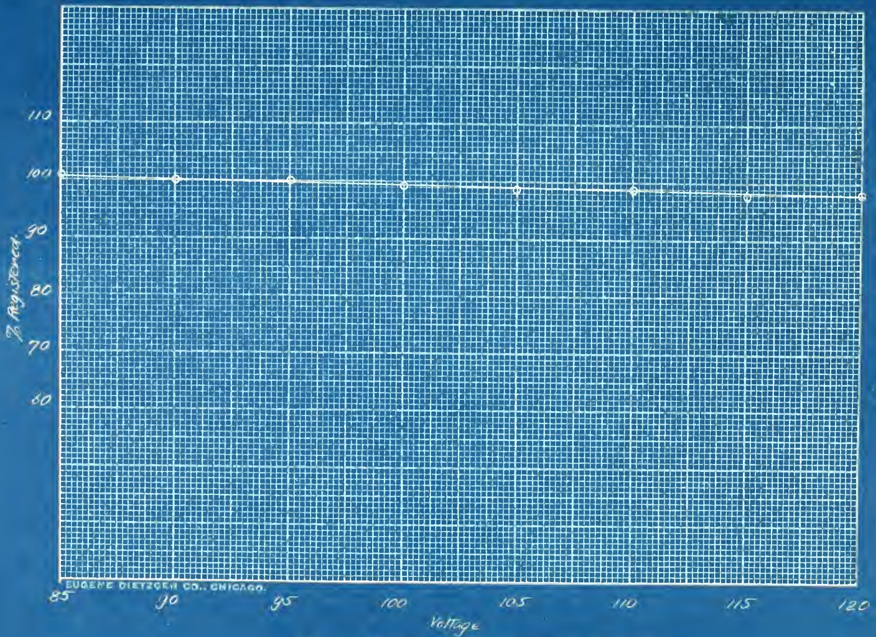
Data showing the effect of change of voltage at 125 % load.

Current =12.5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	1062.5	1072.	100.9
90	1125.	1123.	99.9
95	1187.5	1182.4	99.9
100	1250.	1237.6	99.2
105	1312.5	1297.	98.7
110	1375.	1360.	99.
115	1437.5	1402.	97.8
120	1500.	1489.	99.





Curve of Thomsen Type C. Integrating Wattmeter
Showing The Effect of Variation of Voltage at 125% Load
With Current and Temperature Constant.

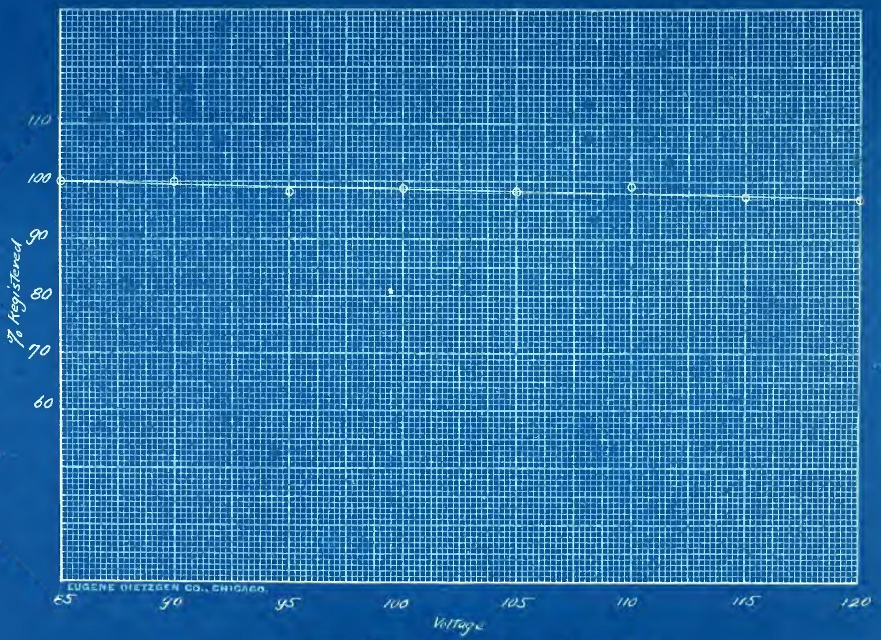
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of voltage at 100 % load.

Current = 10 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	850	850.2	100.
90	900	900.4	100.
95	950	939.	98.8
100	1000	998.1	99.8
105	1050	1028.8	97.9
110	1100	1089.5	99.
115	1150	1121.	97.5
120	1200	1159.8	96.6



Curve of Thomson Type C Integrating Wattmeter
Showing The Effect of Variation of Voltage at 100% Load
With Current and Temperature Constant

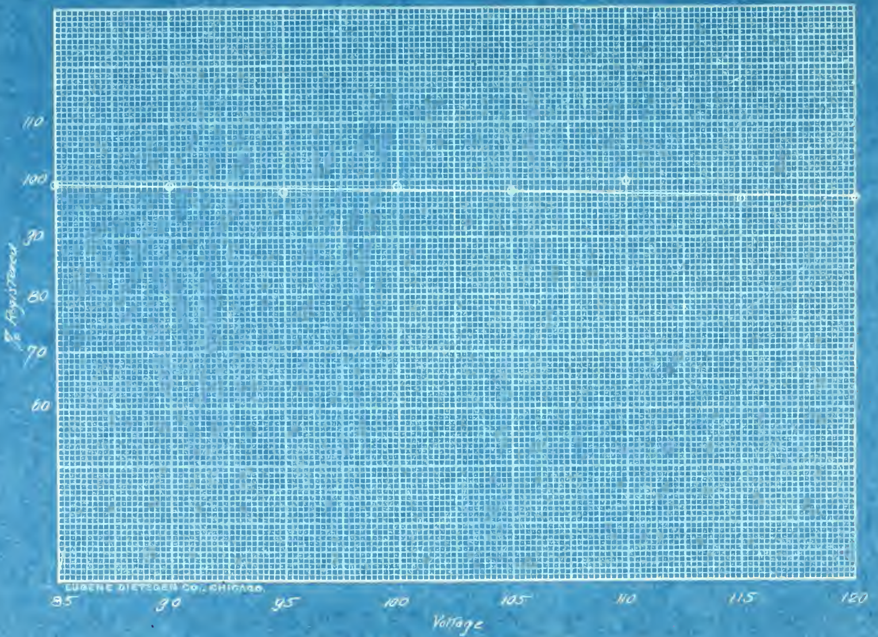
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of voltage at 75 % load.

Current = 7.5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	637.5	633.6	99.4
90	675.	672.4	99.6
95	712.5	698.4	97.9
100	750.	740.	98.9
105	787.5	772.	98.3
110	825.	820.	99.4
115	862.5	832.8	96.6
120	900	870.3	96.9



Curve of Thomson Type C Integrating Wattmeter
Showing the Effect of Variation of Voltage at 75 % Load
With Current and Temperature Constant.

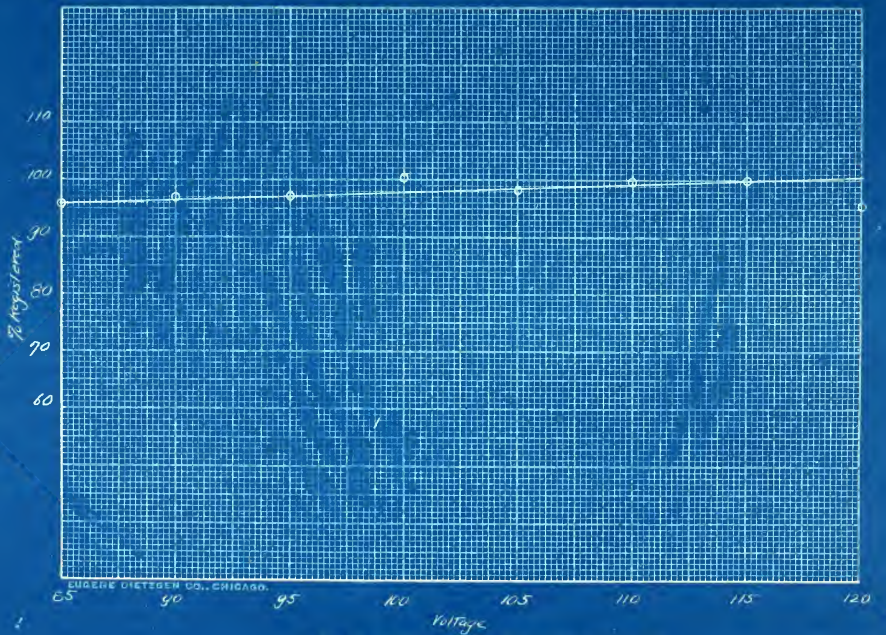
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of voltage at 50 % load.

Current = 5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	425	406.8	95.9
90	450	435.6	96.9
95	475	460.8	97.1
100	500	504.4	100.5
105	525	516.8	98.6
110	550	549.2	99.9
115	575	576.8	100.1
120	600	578.	95.3



Curve of Thomson Type C. Integrating Wattmeter
Showing The Effect of Variation of Voltage at 50% Load
With Current and Temperature Constant.

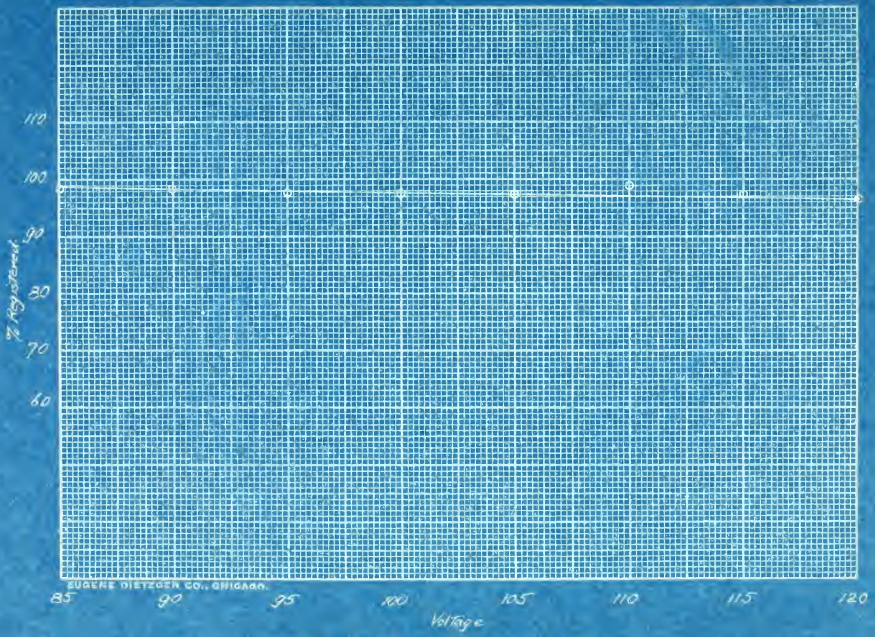
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of voltage at 25 % load.

Current = 2.5 amperes

Temperature = 25 degrees C.

VOLTAGE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
85	212.5	210.1	98.7
90	225.	222.	98.7
95	237.75	232.1	97.8
100	250.	243.9	97.6
105	262.5	256.3	97.6
110	275.	272.6	99.2
115	287.5	280.4	97.7
120	300.	289.2	96.5



Curve of Thomson Type C Integrating Wattmeter
Showing the Effect of Variation of Voltage at 25 % Load
With Current and Temperature Constant

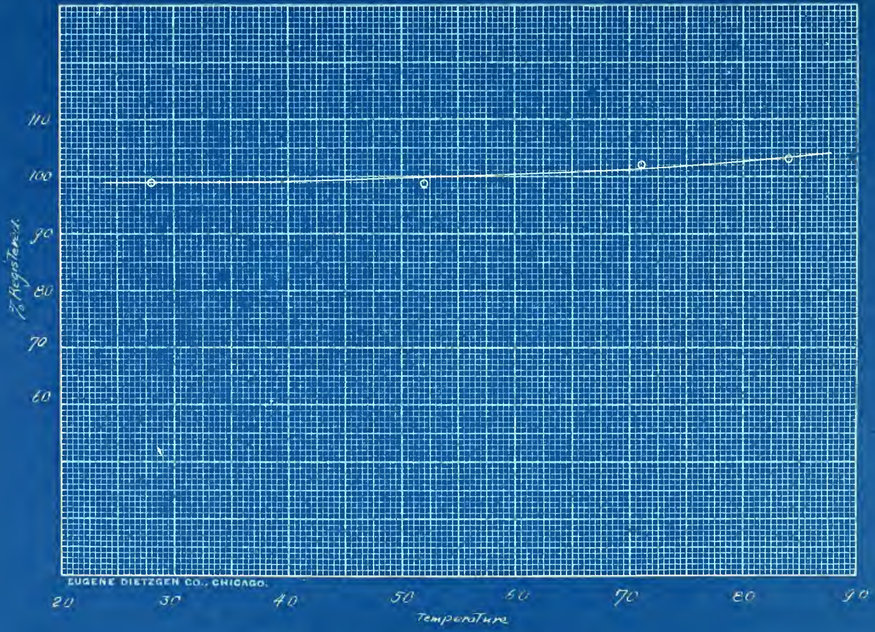
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of temperature at 150 % load.

Potential = 110 volts

Current = 15 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
28	1650	1638	99.3
52	1650	1625	98.6
71	1650	1685	102.1
94	1650	1703	103.3



Curve of Thomson Type "C" Integrating Wattmeter
Showing the Effect of Variation of Temperature
At 150% Load with Pressure and Current Constant.

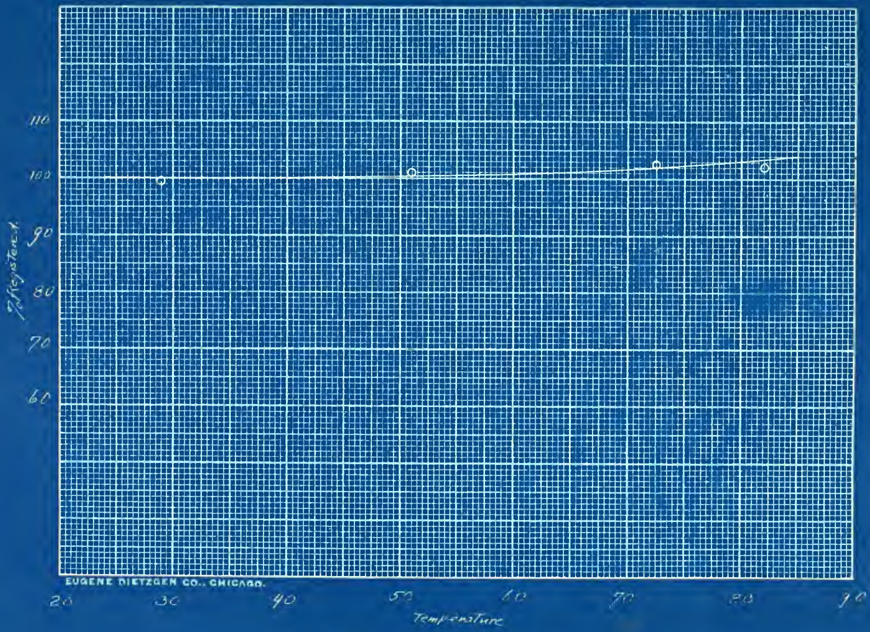
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of temperature at 125 % load.

Potential = 110 volts

Current = 12.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
29.	1375	1367	99.6
51.	1375	1390	101.1
72.5	1375	1409	102.5
82.	1375	1404	102.



Curve of Thomson Type "C" Integrating Wattmeter
Showing The Effect of Variation of Temperature
At 125% Load with The Pressure and Current Constant.

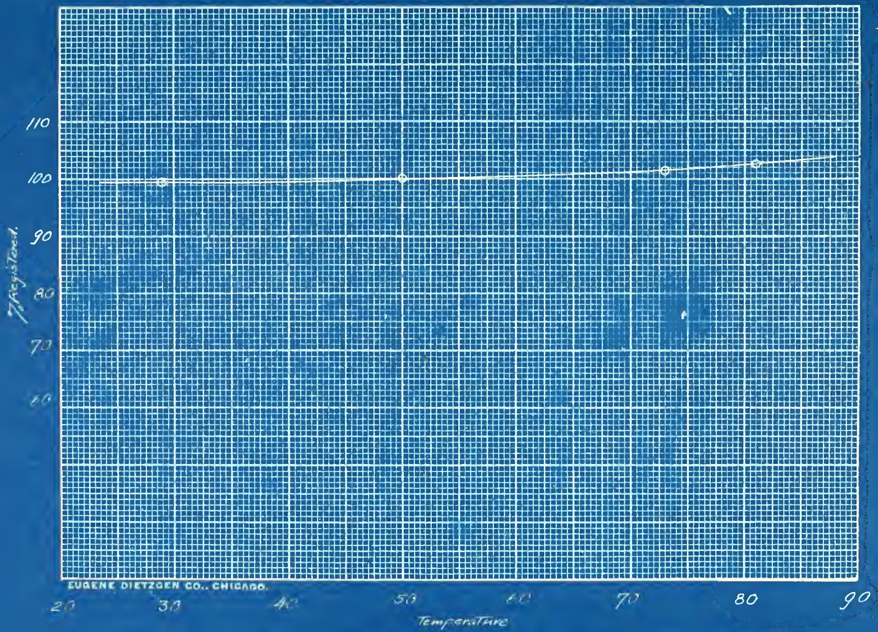
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of temperature at 100 % load.

Potential = 110 volts

Current = 10 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
29.	1100	1091	99.5
50.	1100	1102	100.2
72.8	1100	1118	101.5
81.	1100	1129	102.7



Curve of Thomson Type "C" Integrating Wattmeter
Showing the Effect of Variation of Temperature
At 100% Load with Pressure and Current Constant.

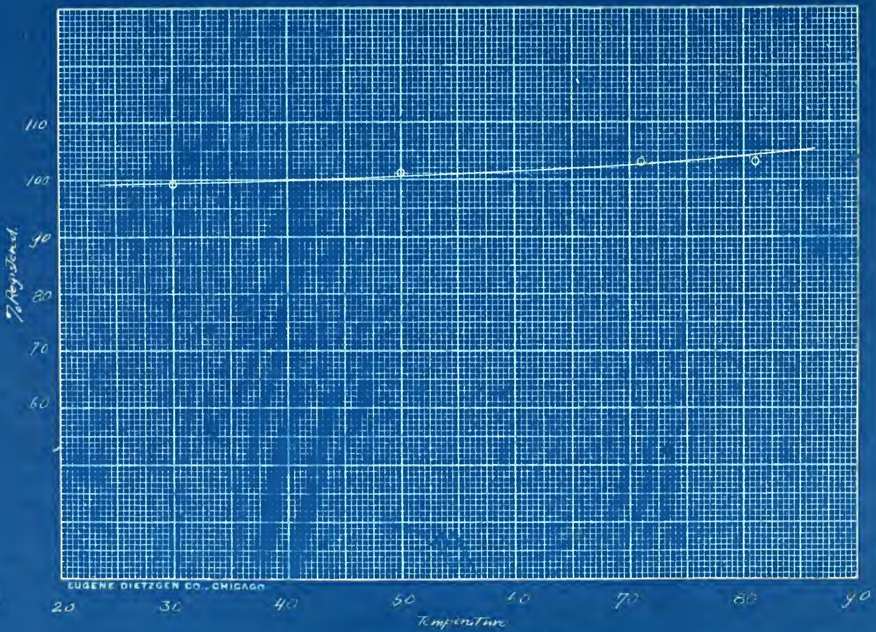
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of temperature at 75 % load.

Potential = 110 volts

Current = 7.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30	825	820	99.5
50	825	836	101.3
71	825	853	103.3
91	825	849	102.9



Curve of Thomson Type "C" Integrating Wattmeter
Showing The Effect of Variation of Temperature
At 75% Load with Pressure and Current Constant.

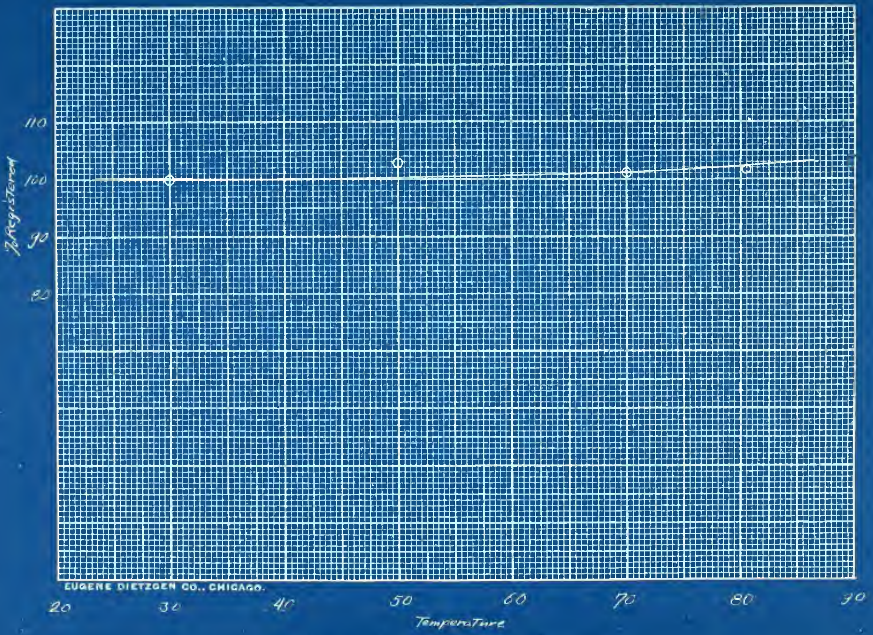
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of temperature at 50 % load.

Potential = 110 volts

Current = 5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30	550	550	100.
50	550	566	102.9
70	550	556	101.
81	550	530	101.6



Curve of Thomson Type "C" Integrating Wattmeter
Showing The Effect of Variation of Temperature
AT 50% Load with Pressure and Current Constant

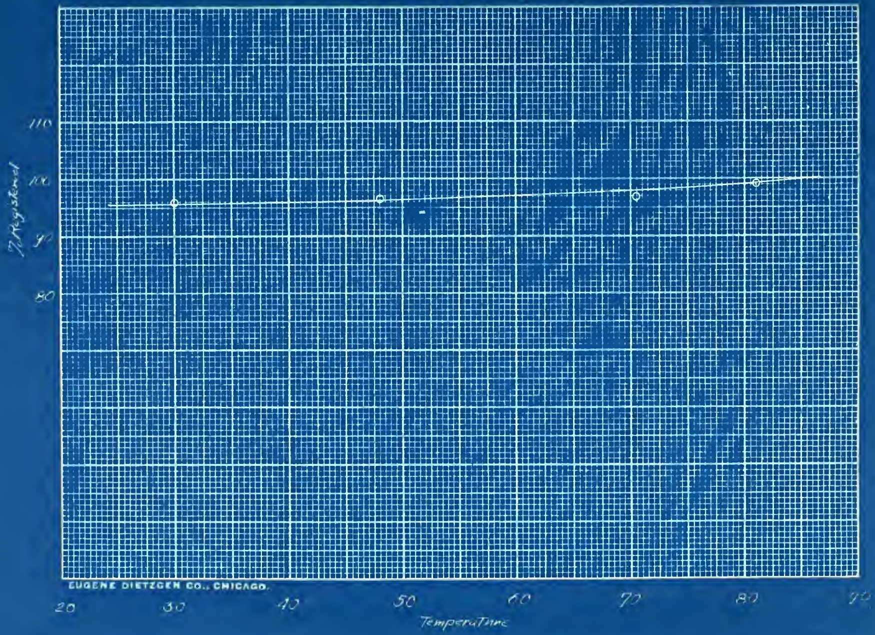
Thomson-Houston Type "C" Integrating Wattmeter.

Data showing the effect of change of temperature at 25 % load.

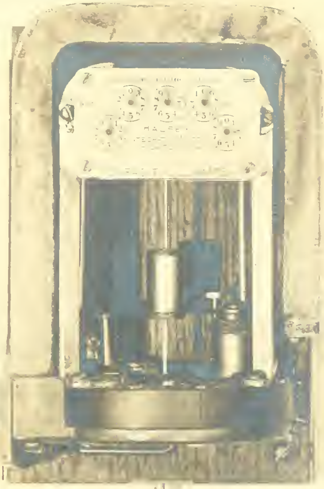
Potential = 110 volts

Current = 2.5 amperes

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30.	275	264.	96.1
48.	275	265.5	96.6
70.5	275	266.	96.9
81.	275	274.	99.6



Curve of Thomson Type "C" Integrating Wattmeter
Showing the Effect of Variation of Temperature
At 25% Load with Pressure and Current Constant.



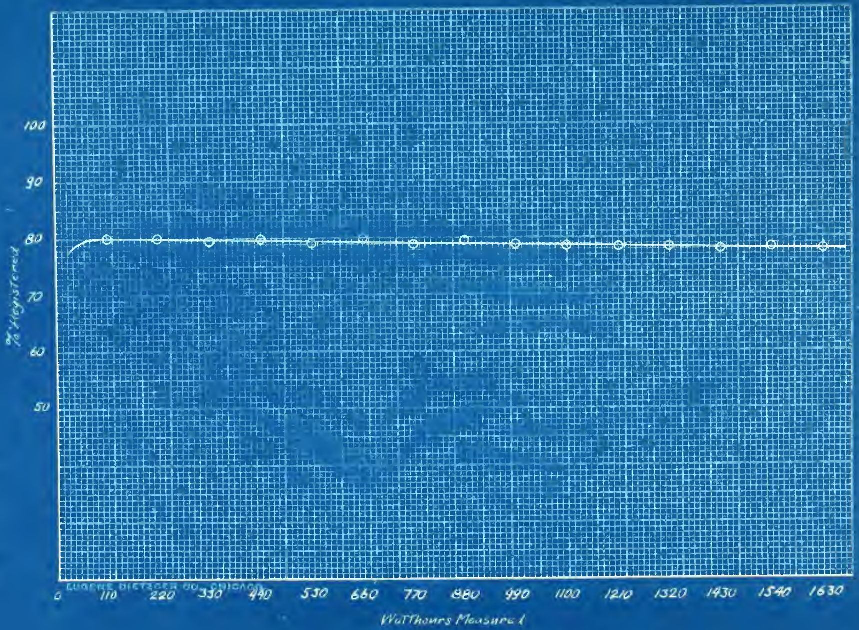
Halsey Integrating Wattmeter.

Data showing the effect of change of current at normal voltage.

Potential = 110 volts

Temperature = 25 degrees C.

CURRENT	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
1	110	87.8	79.9
2	220	176.	80.1
3	330	263.	79.7
4	440	352.	80.
5	550	431.5	79.9
6	660	526.5	79.8
7	770	609.5	79.
8	880	698.7	79.3
9	990	782.3	79.
10	1100	860.4	79.5
11	1210	961.	79.5
12	1320	1038.	78.5
13	1430	1111.	77.9
14	1540	1207.	78.5
15	1650	1296.	79.



Performance Curve of Halsey Integrating Wattmeter
Showing the Effect of Variation of Current
With Constant Voltage and Temperature

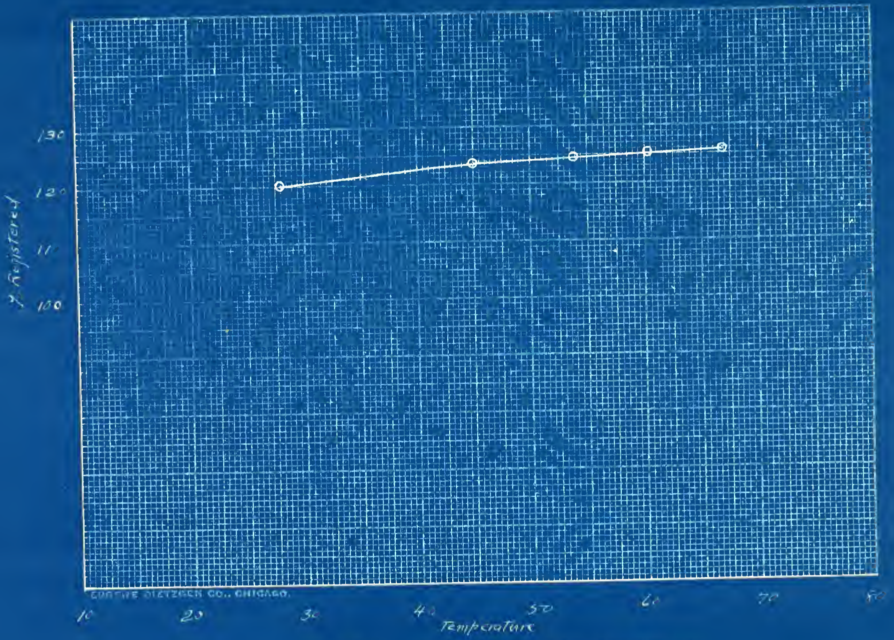
Halsey Integrating Wattmeter.

Data showing the effect of change of temperature at 150 % load.

Potential = 110 volts

Current = 15 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
28.	1560	1890	121.0
45.	1560	1931	123.8
54.5	1560	1942	124.4
60.3	1560	1949	124.9
67.	1560	1970	126.2



Performance Curves of Halsey Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 150% Load with Constant Current and Voltage

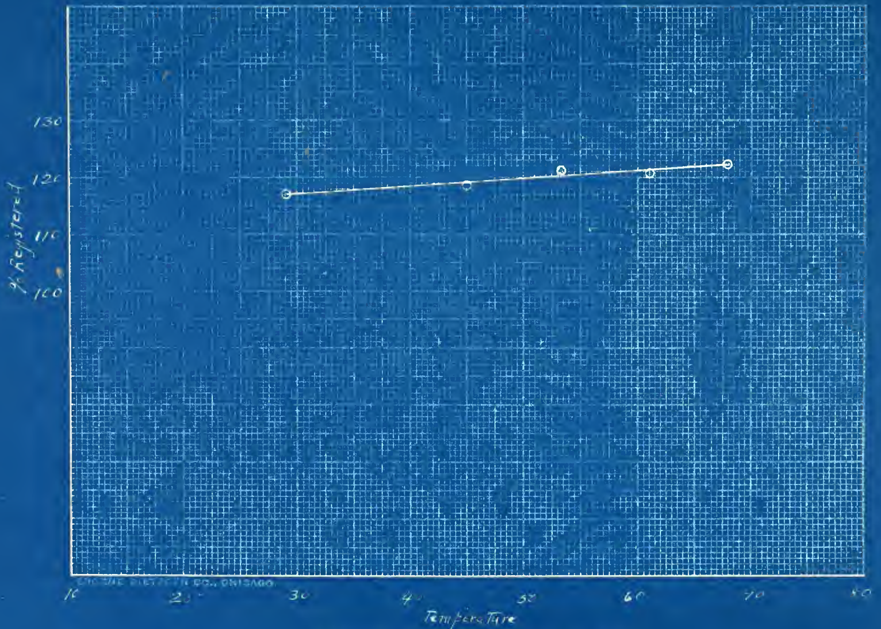
Halsey Integrating Wattmeter.

Data showing the effect of change of temperature at 125 % load.

Potential = 110 volts

Current = 12.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
29.	1375	1615	117.3
45.	1375	1632	118.5
53.4	1375	1661	121.
61.	1375	1658	120.5
68.	1375	1680	122.1



Performance Curve of Halsey Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 125% Load with Constant Current and Voltage

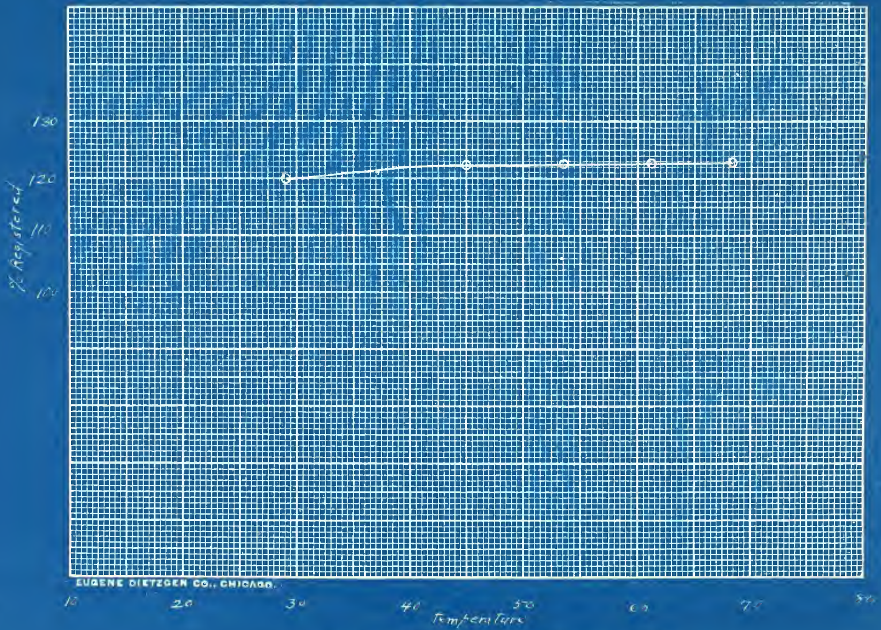
Halsey Integrating Wattmeter.

Data showing the effect of change of temperature at 100 % load.

Potential = 110 volts

Current = 10 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
29.	1100	1320	120.
45.	1100	1349	122.6
53.5	1100	1350	122.8
61.2	1100	1350	122.8
68.	1100	1349	122.5



Performance Curve of Halsey Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 100% Load with Constant Voltage and Current.

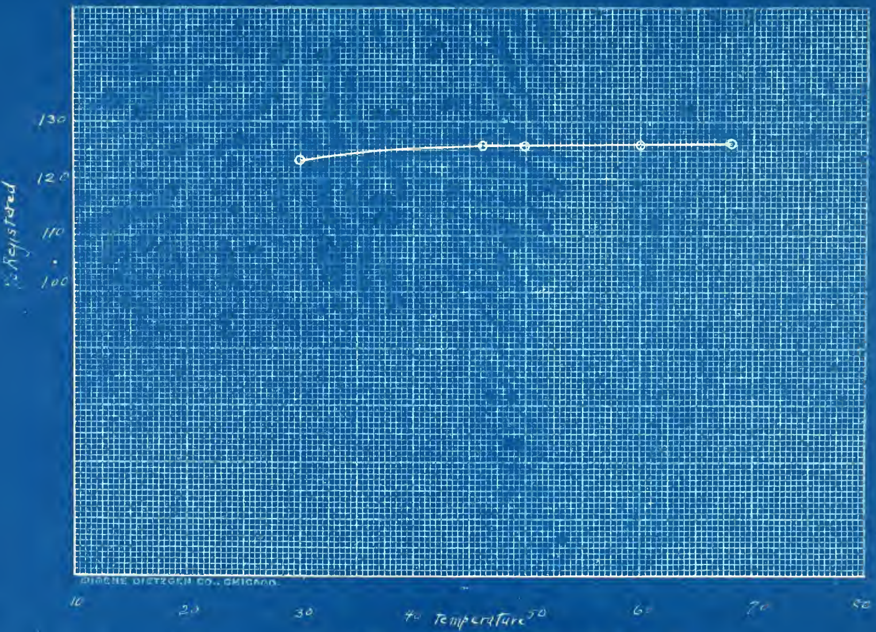
Halsey Integrating Wattmeter.

Data showing the effect of change of temperature at 75 % load.

Potential = 110 volts

Current = 7.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30.	825	1011	123.
46.8	825	1039	125.8
50.	825	1039	125.8
57.	825	1040	125.9
60.	825	1041	126.



Performance Curve of Halsey Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 75% Load With Constant Current and Voltage

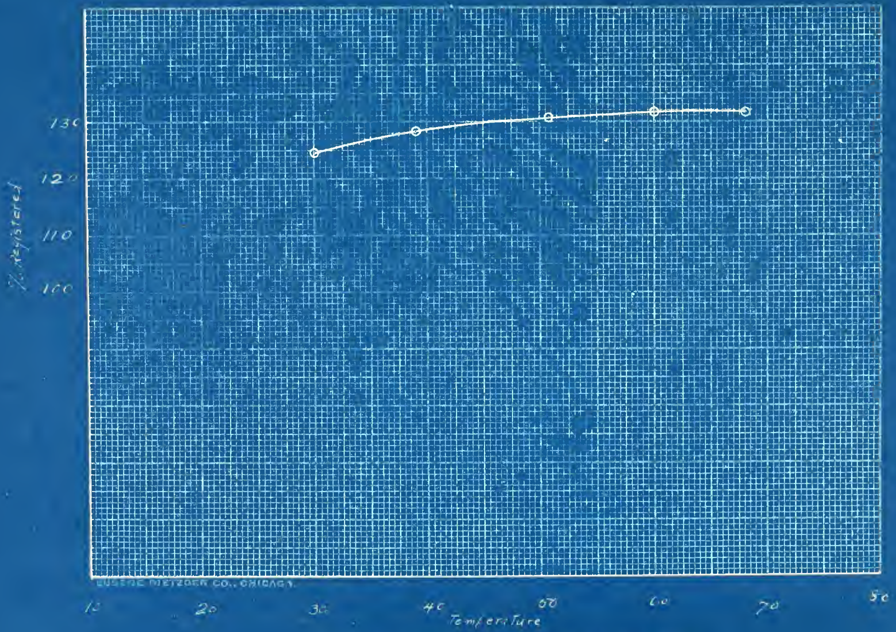
Halsey Integrating Wattmeter.

Data showing the effect of change of temperature at 50 % load.

Potential = 110 volts

Current = 5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30.	550	686	124.5
45.8	550	717	130
50.9	550	720	130.7
60.	550	724	131.4
68.	550	725	131.8



Performance Curve of Halsey Integrating Wattmeter
Showing the Effects of Variation of Temperature
at 50 % Load with Constant Voltage and Current

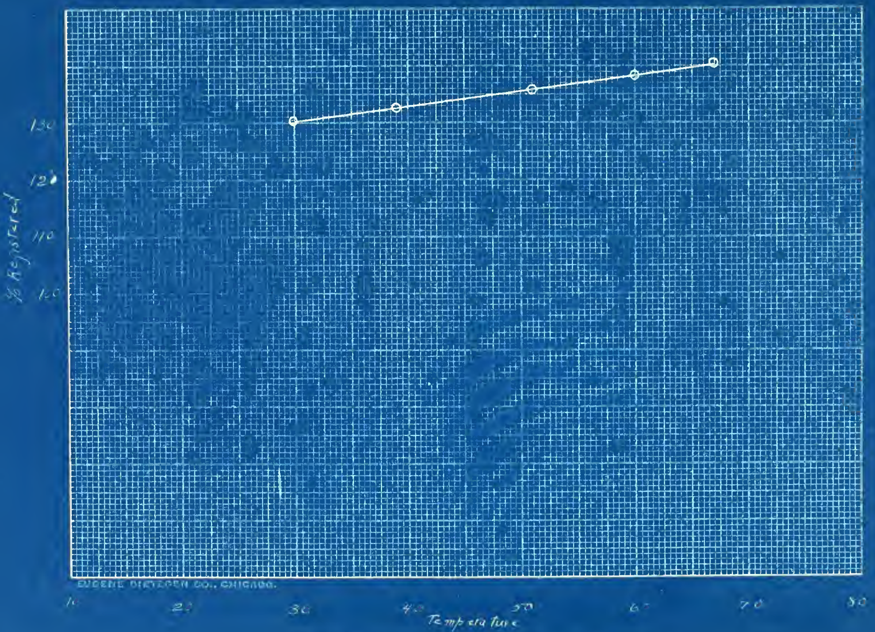
Halsey Integrating Wattmeter.

Data showing the effect of change of temperature at 25 % load.

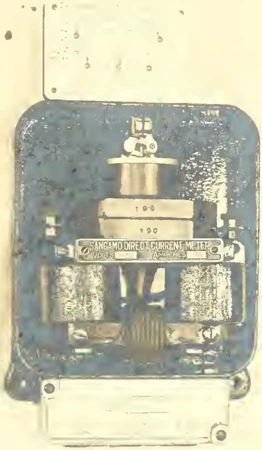
Potential = 110 volts

Current = 2.5 amperes.

TEMPERATURE	WATTHOURS MEASURED	WATTHOURS REGISTERED	% REGISTERED
30	275	358	130.
45	275	369	134.1
51	275	372	135.2
59	275	380	138.1
67	275	387	140.7



Performance Curve of Halsey Integrating Wattmeter
Showing the Effect of Variation of Temperature
at 25% Load with Current and Voltage Constant.


190
190
SANGAMO DIRECT CURRENT METER
VOLTS
AMPERES